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WEAR RESISTANT RUBBER TANK TRACK PADS

by

EDWARD W. BERGSTROM

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OCTOBER 1975

TECHNICAL REPORT

US ARMY ARMAMENT COMMAND

PREPARED BY

RESEARCH DIRECTORATE

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Certain chemical heat stabilizers provided a significant reduction in heat buildup to various experimental track pad vulcanizates while others provided a significant improvement in tear resistance at 250°F. Although the resistance to heat buildup through the use of wire cloth may be improved in some cases the use of wire cloth in track pads is not feasible because of the chunking and delamination problems associated with its use under dynamic conditions. Blending natural or synthetic natural rubber with SBR 1500, Stereon 750, HYTRANS or SBR/polybutadiene improved the resistance to abrasion,

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20. ABSTRACT

tear, and crack growth in most cases. An EPDM/pale crepe blended vulcanizate had significantly improved resistance to abrasion and crack growth when compared to a vulcanizate prepared from EPDM only, but tear resistance was poorer. Blending Stereon 750 or HYTRANS elastomers with fast-curing EPDM and brominated butyl provided no significant improvement in resistance to tear, abrasion, or crack growth when compared to the originally developed Stereon 750 and HYTRANS base compounds. The addition of Santoweb D fibers to various experimental track pad compounds had an adverse effect on the resistance to crack growth.

A summary is included of the efforts of the past 13 years in attempting to improve the wear resistance of rubber track pads. The average service life of pads was approximately 1200-2000 miles when this work was begun. On the basis of service tests conducted on experimental compounds developed during this study, it is reasonably certain that a 3500 mile pad is now a reality.

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CONTENTS

ILLUSTRATIONS

TABULAR DATA

Title	Page

OBJECTIVE:

The object of this work was to develop a rubber pad for tracked vehicles that would provide reliable service for 5000 miles of vehicle operation.

BACKGROUND:

For the past 13 years, the Research Directorate at Rock Island Arsenal has been involved in funded programs to improve the wear resistance of rubber tank track pads. The studies began in FY63 and have been continuous since that time. Particular emphasis was placed on the improvement of the wear resistance of rubber pads for the T142 and T130 tracks since unit procurement for these tracks is, by far, the largest for track currently in use. The T142 track is used on the M48-and M60-series tanks, and the T130 track is used on the M113 personnel carrier. The operating life and reliability of the T142 track, developed to replace the T97E2 track, is limited to approximately 2000 miles because of the limitations of the rubber components. While the metal track remains operational for 5000 miles or more, the average life of the rubber pads is seldom more than 2000 miles. A rubber track pad that would match the operational life of the metallic track is highly desirable and would result in increased reliability and reduced maintenance, and in a tremendous cost savings in the purchase of replacement pads. Commercially available track pads fabricated from SBR fall far short of the objective. Past efforts of this laboratory[1-10] have been directed toward (1) the development of pads

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1. Veroeven, W.M., "Synthesis and Evaluation of Polyurethane Elastomers," Rock Island Arsenal Laboratory Technical Report 63-1242, April 1963.
2. Veroeven, W.M., and J.W. McGarvey, "Polyurethane Elastomers for Track Pad Applications," Rock Island Arsenal Laboratory Technical Report 63-2900, September 1963.
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9. Bergstrom, E.W.,"Development of Wear-Resistant Elastomers for Track Pads," Research Directorate Technical Report SWERR-TR 72-74, October 1972.
10. Bergstrom, E.W., "Material Development for Improved Rubber Track Pads," Research Directorate Technical Report R-TR-74-021, April, 1974.

that would match the operational life of the metal track and (2) the development of a laboratory test or tests that could be used in the prediction of the wear resistance of experimental track pad compounds without resorting to costly and time consuming service tests. Significant progress has been made in both areas. Experimental track pads based on stereospecific SBR (Stereon 750), SBR/polybutadiene blends (Philprene 1609/Cis-4 1350 (or Cis-4 1351), Ameripol 1834/Ameripol CB 1352) and alfin catalyzed copolymers of butadiene/styrene and butadiene/isoprene (HYTRANS) have exhibited a 50 percent or greater improvement in tread wear during service tests when compared to commercial SBR pads. The service testing of commercially prepared pilot lots of pads based on stereospecific SBR and SBR/polybutadiene blends has confirmed this improvement in tread wear. The uncertainty regarding the future commercial availibility of the alfin catalyzed copolymers of butadiene/isoprene and butadiene/styrene has precluded the preparation of pilot lots of pads based on these elastomers. Correlation was found between service test wear ratings and laboratory test data obtained for tear strength, resistance to crack growth, and abrasion resistance. This report covers work done on the improvement of the wear resistance of rubber track pads since issuance of the previous report[10] plus a summary of all work done on this problem since the initial investigation began in FY63.

APPROACH:

Rubber compounds designed for initial laboratory evaluation were mixed on a 12-inch rubber mill. Tensile strength, elongation, and modulus were determined at ambient and elevated temperatures by use of a Scott Model L-6 rubber tensile tester equipped with a Scott Model HTO hot tensile oven and autographic recorder-controller. Each dumbbell specimen was placed in the grips of the tester and conditioned for six minutes at the elevated temperature before being tested. All other physical properties were determined by ASTM procedures where applicable. Physical properties of experimental compounds were compared with those of the Research Directorate SBR control compound which has given wear ratings similar to those of commercial SBR compounds in numerous service tests.

A Number 1 Banbury mixer was used to mix all compounds selected for the preparation of experimental track pads. The Banbury mixed compound was transferred to a 30-inch mill for additional mixing and sheeting-out. The cooled stock was later transferred to an 18-inch mill for warmup and for sheeting-out to the desired thickness for preparation of track pad preforms from rolled stock.

10 Bergstrom, Ibid.

The following surface preparations were made on the track pad metal backup plates (inserts) and on the ASTM D429-68 steel test panels prior to vulcanization-bonding to the rubber stocks: degreasing, glass beadblasting, solvent-wiping, brush application of bonding agent, and drying.

Service tests of experimental track pads were arranged through the U.S. Army Tank-Automotive Command (TACOM), Warren, Michigan.

The following wear (durability) rating was used to compare the performance of the rubber track pads tested:

$$\text{Volume Wear Rating} = \frac{\text{Average volume loss of commercial SBR control pads}}{\text{Average volume loss of experimental pads}} \times 100$$

Compound formulations are given in Table 1.

RESULTS AND DISCUSSION:

Brass-plated wire cloth (National-Standard Company, 16x14 mesh, .013 Hi-Carbon C-1055 brass-plated warp wire x .020 Low Carbon C-1008 steel wire with no coating fill wire), when laminated with rubber in alternate horizontal layers (seven layers of rubber and six layers of wire cloth) was previously found[10] to provide outstanding improvement in resistance to heat buildup of experimental track pad compounds in laboratory tests with the Firestone Flexometer. Experimental track pads containing the wire cloth reinforcement, however, displayed poor wear resistance in service tests.[10] Examination of the wire reinforced pads upon completion of test revealed that the wire cloth actually had an adverse affect on wear resistance. Delamination of the pads in the area of the wire cloth resulted in excessive chunking and tearing and premature loss of rubber, as shown in Figure 1. Tests were run using the Firestone Flexometer to determine if lesser amounts (three layers) of wire cloth positioned horizontally at different points within the specimen or the same amount (six layers) of wire cloth positioned vertically within the specimen would display the outstanding resistance to heat buildup exhibited by specimens containing six layers of wire cloth positioned evenly throughout. Firestone Flexometer specimens were prepared, as shown in Figure 2, by lamination of the wire cloth with the uncured rubber and then compression molding the specimens in the usual manner. Each piece of wire cloth measured 1/2 inch by 1 1/2 inches and weighed approximately one gram. When six pieces of wire cloth were used in the preparation of the specimens, the total wire cloth content amounted to approximately 20 parts/100 rhc, by weight, of rubber. The resistance-to-heat buildup was determined by use of the Firestone

10 Bergstrom, *Ibid*

Flexometer. The time required for the temperature to rise from 100^{o}F to 200^{o}F was measured when the specimens were subjected to test conditions of 0.25-inch throw and 600-pound loading. Test results are given in Table 2 in which the Research Directorate SBR 1500 control compound (S152-1) was used as the base. The use of only three layers of wire cloth positioned horizontally in various areas within the specimens was not as effective as six layers in the improvement of the resistance-to-heat buildup. Although the specimens containing three layers of wire cloth exhibited no tearing or delamination in this test, the time for the temperature to rise from 100^{o}F to 200^{o}F was much shorter for these specimens than for the specimens containing six layers of wire cloth positioned horizontally (23 or 28 minutes vs. 104 minutes). If the specimens containing the three layers of wire cloth had been flexed as long as 104 minutes, the dynamic action of the wire cloth on the rubber may have induced some tearing of the rubber, regardless of deterioration due to heat buildup. The specimens containing six layers of wire cloth positioned vertically had much poorer resistance-to-heat buildup than the control specimens and exhibited significant tearing of the rubber around the wire cloth. Even though resistance-to-heat buildup may be improved in some cases, the use of wire cloth in track pads is not feasible because of the chunking and delamination problem associated with its use under dynamic conditions. The problem may be similar to that observed in steel-belted radial tires operated at high speeds. In the 7 April 1975 issue of Rubber & Plastics News, the Department of Transportation gave warning that steel-belted radials may disintegrate at high speeds due to tread and belt separation. Similarly, on 14 March 1975, the U.S. Law Enforcement Assistance Administration (LEAA)of the Department of Justice issued a warning that steel-belted radial tires can break down and disintegrate at high speeds.

Numerous potential chemical heat stabilizers were evaluated in the Research Directorate SBR 1500 control compound (S152-1) and in proven wear-resistant experimental track pad compounds based on Stereon 750 (stereospecific SBR) (S227-2), Philprene 1609/Cis-4 1350 (SBR/polybutadiene blend) (S212-2), and HYTRANS 1227-289-1 (alfin catalyzed copolymer of butadiene/styrene) (S223-4) to determine their effect on the resistance to heat buildup. The evaluation of these heat stabilizers also included the determination of their effect on (1) stress-strain properties at ambient temperature, 300^{o}F and after aging 70 hours at 212^{o}F, and (2) tear, Die C, at ambient and 250^{o}F. These results are given in Tables 3-6 and are summarized below:

1. <u>Heat Stabilizers Which Provided Significant Reduction in Heat Buildup (Firestone Flexometer)</u>

<u>Compound Type and Number</u>	<u>Heat Stabilizer</u>
a. Research Directorate SBR 1500 control compound (S152-1)	Dythal (dibasic lead phthalate) Cadmium oxide A189 (silane coupling agent)

Compound Type and Number	Heat Stabilizer
b. Stereon 750 (S227-2)	Dythal Cadmium oxide
c. Philprene 1609/Cis-4 1350 (S212-2)	Dythal Cadmium oxide
d. HYTRANS 1227-289-1 (S223-4)	Dythal Cadmium oxide Manganese Dioxide

2. Heat Stabilizers Which Provided Significant Improvement in Retention of Tear Strength When Measured at 250°F

Compound Type and Number	Heat Stabilizer
a. Research Directorate SBR 1500 control compound (S152-1)	Dyphos (dibasic lead phosphite) A189 Manganese dioxide Rio Resin
b. Stereon 750 (S227-2)	None
c. Philprene 1609/Cis-4 1350 (S212-2)	Dyphos A189
d. HYTRANS 1227-289-1 (S223-4)	None

3. None of the heat stabilizers significantly improved the retention of physical properties measured at 300°F or after aging 70 hours at 212°F.

SBR 1500 vulcanizates reinforced with silica (Hi Sil 233)/ carbon black and silica/ground quartz (Neo Novacite)/carbon black in conjunction with a silane coupling agent (A189) were also evaluated for resistance to heat build-up and heat resistance in general. Silica-reinforced SBR tire tread stocks were reported[11] to have superior resistance to cutting, chipping, and tear over carbon black reinforced stocks, and silica/ground quartz reinforcement provided[12]

11 Letter report from PPG Industries, Inc., date 6 June 1972.
12 Bergstrom, E.W., "Additives for Improving Heat Stability of Silicone Vulcanizates," Rock Island Arsenal Laboratory Technical Report 61-3505, 26 September 1961.

excellent heat resistance to silicone vulcanizates. The results of this evaluation are given in Table 7 in comparison with the Research Directorate control compound (S152-1), and show the following:

1. The Hi Sil 233/Neo Novacite/Statex 160 reinforced vulcanizates containing the A189 silane coupling agent (S152-170 and S152-171) exhibited significantly improved resistance-to-heat buildup over that of the S152-1 control compound, but had poorer tear resistance at ambient temperature and at 250°F.

2. The Hi Sil 233/Statex 160 reinforced vulcanizates, with or without the A189 silane coupling agent (S152-166, S152-167 and S152-168), had somewhat better tear resistance at ambient temperature than the S152-1 control compound, but had poorer or equivalent resistance to heat buildup.

3. The effectiveness of the A189 silane coupling agent is evident in all cases in which it was used, as shown by an increase in ambient tensile strength and moduli, and a decrease in ultimate elongation as the quantity of A189 was increased from zero to 1.0 part/100 rhc.

4. The physical properties of the Hi Sil 233/Statex 160 reinforced vulcanizates (with or without A189) and the Hi Sil 233/Neo Novacite/Statex 160 reinforced vulcanizates (with or without A189) measured at ambient temperature and at 300°F, and after 70 hours of aging at 212°F are in general poorer than those of the S152-1 control compound. The properties of S152-168 come close to equaling those of the control.

Because of the oil shortage, the availability of synthetic rubbers (especially those based on styrene, butadiene, and chloroprene) began to decrease significantly during the winter months of 1973-1974. The December 1973 issue of Rubber Age carried the statement that the ready availability of natural rubber (pale crepe and smoked sheet) might tend to diminish the problem of synthetic rubber shortages. For this reason, Rodman Laboratory began to evaluate the properties of vulcanizates prepared from blends of natural rubber with elastomers that had provided pads with significant resistance to tread wear in various service tests. Stereon 750, alfin catalyzed copolymers of butadiene/styrene and butadiene/isoprene (HYTRANS rubbers), and an SBR/Cis-4 polybutadiene blend were included. The effect of blending natural rubber with SBR 1500 in the Research Directorate control formulation (S152-1) was also studied. The results are given in Tables 8-12 and exhibit the following findings:

1. <u>SBR 1500/Pale Crepe Blends</u>

a. The resistance to tear at both ambient and elevated temperatures, and the resistance to abrasion and crack growth improved dramatically when the ratio of SBR 1500/pale crepe changed from 60/40 to 40/60.

b. Stress-strain properties measured at ambient temperature were not affected as increasing amounts of pale crepe were blended with the SBR 1500. However, the retention of properties measured at 300°F and 400°F improved significantly (on the basis of tensile and elongation retention at 300°F, and retention of elongation at 400°F) as the ratio of SBR 1500/pale crepe changed from 60/40 to 40/60.

c. The flexibility, as measured by ASTM D1043, was better at lower temperatures for the SBR 1500/pale crepe blended vulcanizates than for the vulcanizate prepared from SBR 1500 alone.

2. Stereon 750/Pale Crepe Blends

a. Resistance to tear at both ambient and elevated temperatures improved linearly as increasing amounts of pale crepe were used in Stereon 750/pale crepe blends.

b. Abrasion resistance was adversely affected, but resistance to crack growth was significantly improved when the ratio of Stereon 750/pale crepe changed from 82.5/40 to 55/60.

c. A significant increase occurred in moduli measured at ambient and elevated temperatures as the amount of pale crepe in the Stereon 750/pale crepe blends increased.

d. The low temperature stiffness was poorer for the blended vulcanizates than for vulcanizates prepared from Steron 750 only.

3. HYTRANS (Butadiene/Styrene type)/Pale Crepe Blends

a. Resistance to tear at ambient temperature improved significantly as the HYTRANS/pale crepe ratio changed from 82.5/40 to 55/60. Except for the 27.5/80 HYTRANS/pale crepe blend, resistance to tear at elevated temperatures for the other blends was not significantly different from that of the vulcanizate prepared from HYTRANS only.

b. Resistance to abrasion was significantly better for the blended vulcanizates than for the vulcanizate prepared from HYTRANS only, but no improvement in resistance to crack growth was noted until the pale crepe portion of the blend was increased from 60 to 80 parts.

c. The moduli measured at ambient and elevated temperatures were significantly higher for the blended vulcanizates than for those of the vulcanizate prepared from HYTRANS only.

d. Resistance to low temperature stiffness was somewhat better for the blended vulcanizates than for the vulcanizate prepared from HYTRANS alone when T_{200} values were measured by ASTM D1043.

4. HYTRANS (Butadiene/Isoprene Type)/Pale Crepe Blends

a. Resistance to tear at ambient and elevated temperatures improved linearly as increasing amounts of pale crepe were used in the HYTRANS/pale crepe blends.

b. Resistance to abrasion and crack growth, and resistance to stiffness at low temperature were adversely affected when pale crepe was blended with HYTRANS.

c. Moduli, especially those measured at ambient temperature and at 300°F, increased significantly as increasing amounts of pale crepe were used in the HYTRANS/pale crepe blends.

5. Philprene 1609/Cis-4 1350/Pale Crepe Blends

(As noted in Table 12, supplemental amounts of carbon black, Statex 160, were added to the pale crepe blended vulcanizates as the amount of the master batch carbon black contained in the Philprene 1609 and Cis-4 1350 decreased.)

a. Tear resistance at ambient temperature and resistance to crack growth improved dramatically when the ratio of Philprene 1609/Cis-4 1350/pale crepe changed from 60.9/38.7/40 to 40.6/25.8/60. Tear resistance measured at elevated temperatures increased linearly as the amount of pale crepe in the blends increased.

b. The abrasion resistance was somewhat better for the pale crepe blended vulcanizates than for the vulcanizate prepared from a blend of only Philprene 1609 and Cis-4 1350.

c. Resistance to low temperature stiffness was not significantly affected by the addition of pale crepe. When pale crepe was blended with SBR 1500, Stereon 750, HYTRANS (Butadiene/Styrene Type), and HYTRANS (Buradiene/Isoprene Type), the ozone resistance was adversely affected, as is shown in Tables 8,9,10, and 11. This can be remedied by use of increased amounts of antiozonant.

Because of the success achieved in the improvement of certain properties of SBR 1500, Stereon 750, HYTRANS or SBR/polybutadiene when these elastomers were blended with natural rubber (pale crepe), a study was made to determine the effect of the blending of these same elastomers with a <u>synthetic</u> natural rubber, Ameripol SN 600. Since the most dramatic improvement in most properties occurred in elastomer ratios containing 60 parts of pale crepe, these same blend ratios were chosen for evaluation with the Ameripol SN 600. The results given in Table 13 show that in general the effect on physical properties of the blending of Ameripol SN 600 with the various elastomers was the same

as the effect of the pale crepe when blended with the same elastomers (Tables 8-12). Thus, either natural rubber (pale crepe) or synthetic natural rubber (Ameripol SN 600) could be used interchangeably to significantly improve resistance to tear or abrasion.

Because EPDM vulcanizates are inherently ozone resistant and have excellent age resistance, even at temperatures as high as 250°F, these vulcanizates were considered as choices for use in track pads. However, the EPDM vulcanizates were only as abrasion resistant as the SBR vulcanizates, and experimental track pads prepared from EPDM exhibited no improvement in wear resistance over SBR in service tests. Numerous means of improving the abrasion resistance of a fast-curing EPDM (EP syn 55) were evaluated without success during FY 1973.[10] Because of the significant improvement in abrasion resistance imparted to SBR 1500, HYTRANS (butadiene/styrene type), and SBR/polybutadiene when blended with pale crepe, blends of EPDM/pale crepe were evaluated. These results are given in Table 14 and show that a 40/60 EP syn 55/pale crepe blend (E59-14) has significantly improved abrasion resistance when compared to the EP syn 55 control compound (E59). The addition of pale crepe to EP syn 55 also improved resistance to crack growth (DeMattia tester) and low temperature flexibility (ASTM D1043). Tear resistance, especially at ambient temperature, was not improved. The addition of Dyphos and Rio Resin to the 40/60 EP syn 55/pale crepe blended vulcanizate did not improve tear resistance. The use of these additives, known to improve the tear resistance of SBR 1500 and SBR/polybutadiene vulcanizates, also had an adverse affect on abrasion resistance. Because of the significant improvement in resistance to abrasion and crack growth afforded EPDM when blended with pale crepe, further attempts to improve the tear resistance of this blend would be worthwhile.

In an article[13] appearing in the May 1973 issue of Rubber Age, the introduction to the rubber market of a new high Mooney flame retardant SBR was described by the B.F. Goodrich Chemical Company. The results of the evaluation of this new elastomer, Ameripol 4713, are given in Table 15 in comparison with the Research Directorate control compound (S152-1). The vulcanizate prepared from Ameripol 4713 (S252) exhibited significantly improved resistance to both abrasion and tear at elevated temperatures when compared with compound S152-1, but exhibited poorer resistance to crack growth. Because of the poor resistance to crack growth, the conclusion was

10 Bergstrom, Ibid

13 Shah, A.K., Hallman, R.W. and Sarbach, D.V., "Flame Retardant SBR," Rubber Age, Vol. 105, No. 5, May 1973, pp. 37-42.

that this compound would be unsuitable for rubber track pads. This Laboratory has since learned that Goodrich has withdrawn this elastomer from the market.

At the request of the U.S. Army Tank-Automotive Command (TACOM), Warren, Michigan, work was done on blends of Stereon 750 and HYTRANS (both SBR and butadiene/isoprene types) with a fast-curing EPDM (EP syn 55) and brominated butyl (Polysar Bromobutyl X2). The effect on the blends of an SAF vs. an FEF black, and blends of the two blacks was also studied. These results are given in Tables 16-18. Since the Stereon 750 and HYTRANS elastomers contain 37.5 parts oil, appropriate amounts of the same type of oil were added to the blends so that the parts oil/100 rhc in all compounds would remain the same. Generally, from the results, the conclusion follows that neither the use of blends nor the use of FEF black or FEF/SAF black in place of all SAF black provided significant improvement to the originally developed base compounds (S227-2, S223-4 and B33-4) in the combination of properties essential to provide improved wear-resistant compounds, namely, resistance to abrasion, tear, and crack growth. In no case were all three essential properties improved. Resistance to crack growth was generally better for those compounds in which FEF black only was used, but the tear and abrasion resistance of these compounds was much poorer than the originally developed base compound prepared from Stereon 750 or HYTRANS only, and in which only SAF black was used. Resistance to tear at ambient and elevated temperatures, and abrasion resistance of all the experimental compounds was equivalent or, in most cases, much poorer than that found for the base compounds. Original tensile strengths were also poorer for all the experimental compounds than for the base compounds. None of the experimental compounds were considered suitable choices for track pad evaluation.

During FY1975, a new class of reinforcing fibers was introduced to the market by Monsanto Industrial Chemicals Company.[14] These reinforcing agents are unregenerated cellulose fibers coated with a proprietary polymeric agent for better bonding of the fiber to the rubber and have the trade name "Santoweb". Three grades of the Santoweb fibers are marketed. They are Santoweb D for highly unsaturated polymers such as SBR, natural rubber, polyisoprene, polybutadiene and neoprene; Santoweb H for EPDM, butyl, and other low unsaturated polymers; and Santoweb K for such highly polar polymers as nitriles and urethanes. Santoweb D was evaluated at 5 and 15 parts/100 rhc in compounds based on SBR 1500 (Research Directorate control compound) (S152-1), an SBR 1500/pale crepe blend (A50-3), Stereon 750 (S227-2), Philprene 1609/Cis-4 1351 (S212-2), HYTRANS (SBR type) (S223-4), and HYTRANS (butadiene/isoprene type) (B33-4). Resimene 3520, a modifier recommended by Monsanto for use in conjunction with the Santoweb fibers to enhance rubber-to-fiber bonding, was used at a concentration of 1 part/100 rhc. The results, given in Tables 19-24, show the following:

14 Boustany, K., and Hamed, P., "The Effect of Santoweb Fibers on the Tensile Modulus Properties of Natural and Synthetic Rubber." Paper presented at a meeting of the Philadelphia Rubber Group, September 1974.

1. SBR 1500 (Research Directorate Control Compound)

a. The addition of Santoweb D had an adverse effect on abrasion resistance, resistance to crack growth, ozone resistance, and ambient tensile strength.

b. Tear resistance at ambient temperature was significantly improved by the addition of Santoweb D, but tear resistance at 250°F was not significantly affected.

2. SBR 1500/Pale Crepe Blend

a. Resistance to abrasion, crack growth, and ozone were adversely affected by the addition of Santoweb D. Ambient tensile strength was adversely affected only when 15 parts/100 rhc Santoweb D were employed.

b. Tear resistance at ambient temperature was significantly improved by the addition of Santoweb D, but resistance to tear at 250°F was not significantly affected.

3. Stereon 750

a. The addition of Santoweb D had an adverse effect on resistance to crack growth and ozone. Ambient tensile strength was adversely affected only when Santoweb D was used at the 15-part level.

b. Resistance to tear at ambient was significantly improved by the addition of Santoweb D, but tear resistance at 250°F was not significantly affected.

c. Abrasion resistance was significantly improved by the additon of Santoweb D, particularly at the 5-part level.

4. Philprene 1609/Cis-4 1351 Blend

a. Resistance to abrasion and crack growth and tensile strength at ambient were adversely affected by the addition of Santoweb D.

b. Tear resistance at both ambient and elevated temperatures was significantly improved by the addition of Santoweb D.

5. HYTRANS (SBR type)

a. The addition of Santoweb D had an adverse effect on abrasion resistance, ambient tensile strength, and ozone resistance. Resistance to crack growth was adversely affected only when Santoweb D was used at the 15-part level.

b. Tear resistance at ambient was slightly improved by the addition

of Santoweb D, but tear resistance at 250°F was adversely affected.

6. HYTRANS (Butadiene/Isoprene Type)

a. Resistance to abrasion, crack growth and ozone, as well as tensile strength at ambient, were adversely affected by the addition of Santoweb D.

b. Tear resistance at ambient was somewhat improved by the addition of Santoweb D, but tear resistance at 250°F was slightly poorer for the compounds containing Santoweb D.

Because of the adverse effect of Santoweb D on the resistance to abrasion and/or crack growth, none of the compounds in which Santoweb D was used (Tables 19-24) are considered suitable choices for track pad service testing.

Arrangements were made through TACOM to test Research Directorate experimental T142 track pads in a service test performed at Yuma Proving Ground, Yuma, Arizona, during June through September 1975. Experimental pads selected and prepared for this test were based on the following compounds:

1. Research Directorate SBR 1500 control compound (S152-1).
2. SBR 1500/Pale Crepe Blend (A50-3).
3. Stereon 750 (S227-2).
4. Stereon 750/Pale Crepe Blend (A51).
5. HYTRANS 1697-259-1 (SBR Type) (S223-4).
6. HYTRANS 1697-259-1/Pale Crepe Blend (A52).
7. Philprene 1609/Cis-4 1351 Blend (S212-2).
8. Philprene 1609/Cis-4 1351/Pale Crepe Blend (A54).
9. Stereon 750 (Reinforced with carbon and mineral fillers and containing a silane coupling agent) (S227-21).
10. SBR 1500 (Contains Dyphos for improving retention of tear strength at 250°F) (S152-160).
11. Philprene 1609/Cis-4 1351 Blend (Contains Dyphos for improving retention of tear strength at 250°F (S212-7).

Physical properties determined on the Banbury mixed batches of these compounds are given in Table 25.

In addition to the T142 pads prepared from the compounds listed above, experimental pads having a more rounded contour than the conventional T142 pad (Figure 3) were also prepared for service testing. In previous service tests, the initiation of cracking and chipping was attributed to the sharp edges of the conventional T142 pads, and the theory was that "rounding off" these edges might reduce the shearing action on the edges and, thereby, result in pads having improved wear resistance. Pads having the rounded contour were

prepared from SBR 1500 (Research Directorate Control Compound) (S152-1) and Stereon 750 (S227-2) by grinding off the corners of conventional T142 pads using a rubber grinding wheel. The rounded pads were then coated with one coat of a conventional tire dressing to duplicate the mold skin of the conventional pads.

Results of the service test at Yuma are given in Table 26. Tests were conducted for 500 miles on paved track using an M60A1 vehicle having a total weight of 107,000 pounds. These results show the following:

1. With the exception of Compound S227-21, experimental pads based on Stereon 750, HYTRANS (SBR Type), and Philprene 1609/Cis-4 1351 exhibited significantly improved wear resistance when compared with the commercial controls.

2. The addition of pale crepe to Stereon 750 and Philprene 1609/Cis-4 1351 significantly improved the wear resistance of pads based on these elastomers. The addition of pale crepe did not significantly affect the wear resistance of pads based on SBR 1500 or HYTRANS (SBR Type); however, significant improvement may have become evident if the pads had been run on gravel and cross-country courses.

3. The rounded contour pads based on SBR 1500 and Stereon 750 did not exhibit significantly improved wear resistance over that of the conventionally styled pad.

4. The addition of Dyphos did not improve the wear resistance of pads based on SBR 1500 or Philprene 1609/Cis-4 1351, and pads based on carbon black-mineral filled Stereon 750 exhibited very poor wear resistance.

All research efforts on the development of rubber compounds for use in tank track pads have been concluded by the Research Directorate at this Arsenal. A summary of all work accomplished by this Laboratory on the problem over the past thirteen years is given in the appendix.

CONCLUSIONS:

Although resistance to heat buildup through the use of wire cloth may be improved in some cases, the use of wire cloth in track pads is not feasible because of the chunking and delamination that occur under dynamic conditions.

Certain heat stabilizers provided a significant reduction in heat build-up to various vulcanizates while others provided a significant improvement in tear resistance at 250°F. Dythal (dibasic lead phthalate) and cadmium oxide provided a significant reduction in heat buildup to SBR 1500, Stereon

750, HYTRANS (SBR Type), and a Philprene 1609/Cis-4 1350 blend. Dyphos (dibasic lead phosphite) and A189 (a silane coupling agent) provided a significant improvement in tear resistance at 250°F to SBR 1500 and a Philprene 1609/Cis-4 1350 blend. None of the heat stabilizers significantly improved the retention of physical properties measured at 300°F or after aging 70 hours at 212°F.

Blending of pale crepe with SBR 1500, Stereon 750, HYTRANS or SBR/polybutadiene improved the resistance to abrasion, tear, and crack growth in most cases. Significant improvement was generally noted when the pale crepe portion of the blend was 60 parts. The effect on various physical properties when a synthetic natural rubber (Ameripol SN600) was blended with SBR 1500, Stereon 750, HYTRANS or SBR/polybutadiene was the same as that found when natural rubber (pale crepe) was blended with the same elastomers. Therefore, either natural rubber (pale crepe) or synthetic natural rubber (Ameripol SN 600) can be used interchangeably in those formulations to improve tear, abrasion or crack growth.

In an attempt to improve the abrasion resistance of a fast curing EPDM, various EPDM/pale crepe blends were evaluated. A 40/60 EPDM/pale crepe blend was found to have significantly improved resistance to abrasion and crack growth when compared to a vulcanizate prepared from EPDM only; but the tear resistance of the blend was adversely affected.

The effect of blending Stereon 750 or HYTRANS elastomers with a fast-curing EPDM and brominated butyl was investigated. The effect of an SAF vs. an FEF black, and blends of the two blacks on the blended vulcanizates was also studied. Neither the use of various elastomeric blends nor the use of FEF black or FEF/SAF black in place of all SAF black was found to provide any significant improvement in the originally developed Stereon 750 and HYTRANS base compounds as far as resistance to abrasion, tear, and crack growth was concerned.

Santoweb D fibers, unregenerated cellulose fibers coated with a proprietary polymeric agent for better bonding of the fibers to rubber, were evaluated in SBR 1500, SBR 1500/Pale Crepe, Stereon 750, HYTRANS and SBR/polybutadiene vulcanizates. The Santoweb D fibers had an adverse effect on the resistance to crack growth of all the vulcanizates.

Several experimental compounds, particularly those based on blends of the most wear-resistant elastomers found previously with pale crepe, were considered suitable choices for providing rubber track pads with improved wear resistance. Experimental T142 pads were prepared from these compounds and were service-tested at Yuma Proving Ground. Experimental T142 pads, having a more rounded contour than the conventional T142 pads, were also prepared for service testing at Yuma. Pads based on Stereon 750, HYTRANS (SBR Type), and Philprene 1609/Cis-4 1351 exhibited significantly improved wear resistance when compared with commercial controls. The addition of pale crepe to Stereon 750 and Philprene 1609/Cis-4 1351 significantly improved the wear resistance of pads based on these elastomers. The rounded contour pad did not exhibit significantly improved wear resistance over that of the conventionally styled pad.

This Laboratory believes that the combination of shearing force and ground pressure placed on the rubber track pads, because of the weight of the M60-series tank (100,000 pounds or more), may exceed the capabilities of currently available elastomers to significantly resist such forces under dynamic (vehicle-moving) conditions. Possibly, because of the vehicle weight factor, a 5000-mile T142 rubber track pad may never be a reality, no matter how designed, but a T142 pad having a life of 3500 miles can now be obtained with compounds based on those elastomers described herein.

RECOMMENDATIONS:

Scale-up to production levels (in pilot lot quantities) should be continued by TACOM on all experimental compositions which exhibit significant improvement in wear resistance in service tests.

Any new low-cost general purpose elastomer introduced commercially that might be expected to produce more wear-resistant track pads should be evaluated to advance the state of the art of track pad technology.

ACKNOWLEDGEMENT:

The assistance of Mr. James Ruby of the Research Directorate in the Banbury mixing of the numerous experimental compounds required for track pad preparation is very much appreciated.

The cooperation of Mr. C. Dale Maas, SARRI-PF, Rock Island Arsenal, in granting permission to use this Arsenal's rubber production facilities is also appreciated. The availability of the shop size Banbury mixer and roll mills greatly reduced the time and effort required to mix the large batches of rubber needed in the preparation of the experimental track pads.

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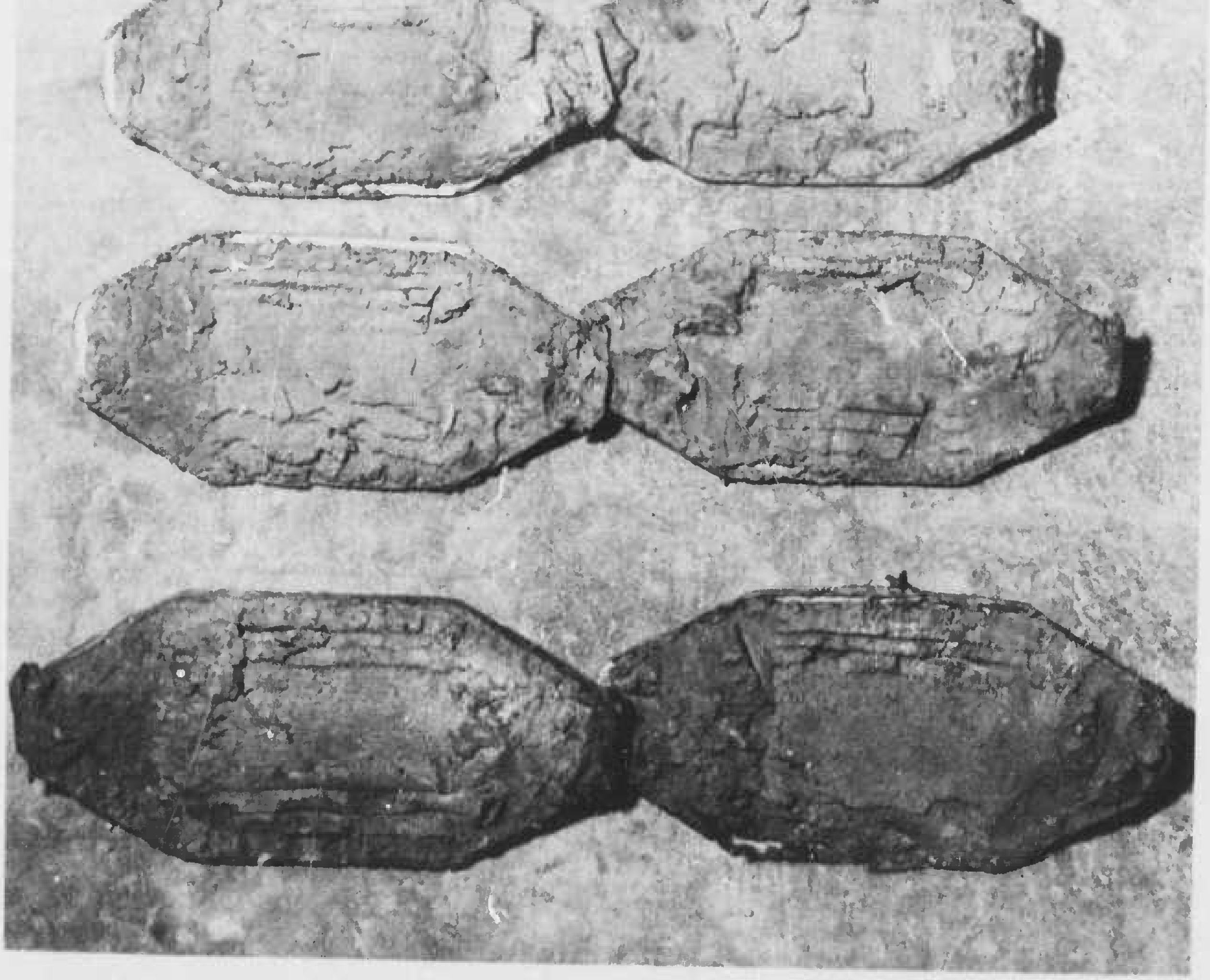
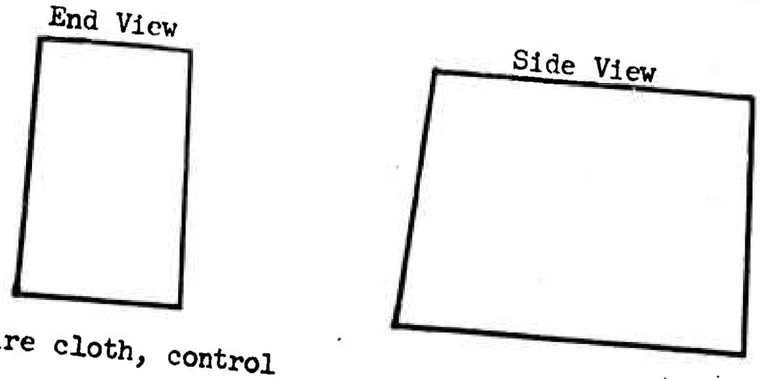


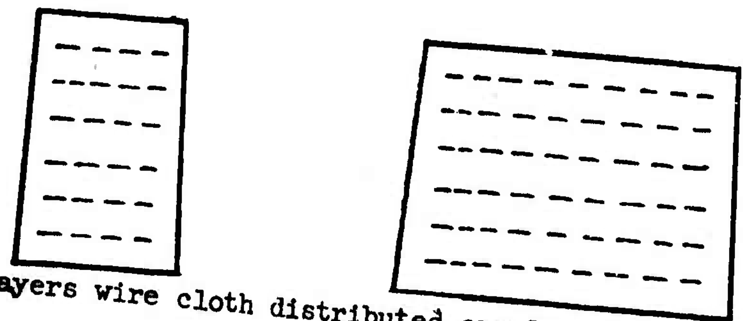
Wire Cloth Reinforced T142 Track Pads After
384-Mile Service Test at Yuma Proving Ground

Figure 1

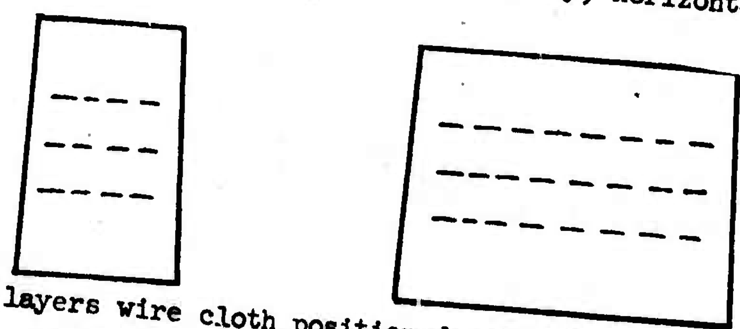
EVALUATION OF WIRE CLOTH IN FIRESTONE FLEXOMETER SPECIMENS



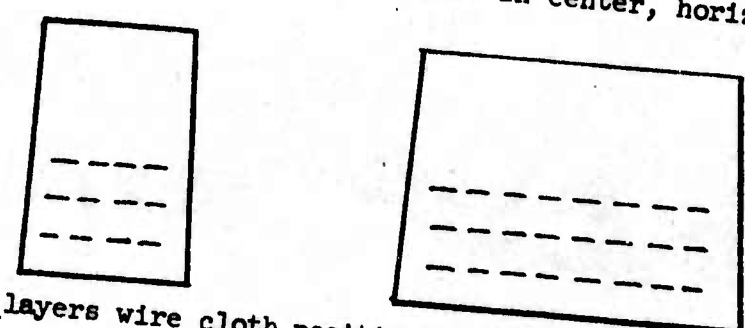
Trial 1-No wire cloth, control



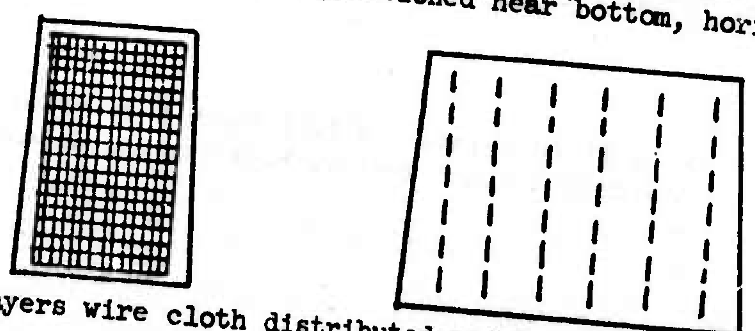
Trial 2-Six layers wire cloth distributed evenly, horizontally



Trial 3-Three layers wire cloth positioned in center, horizontally

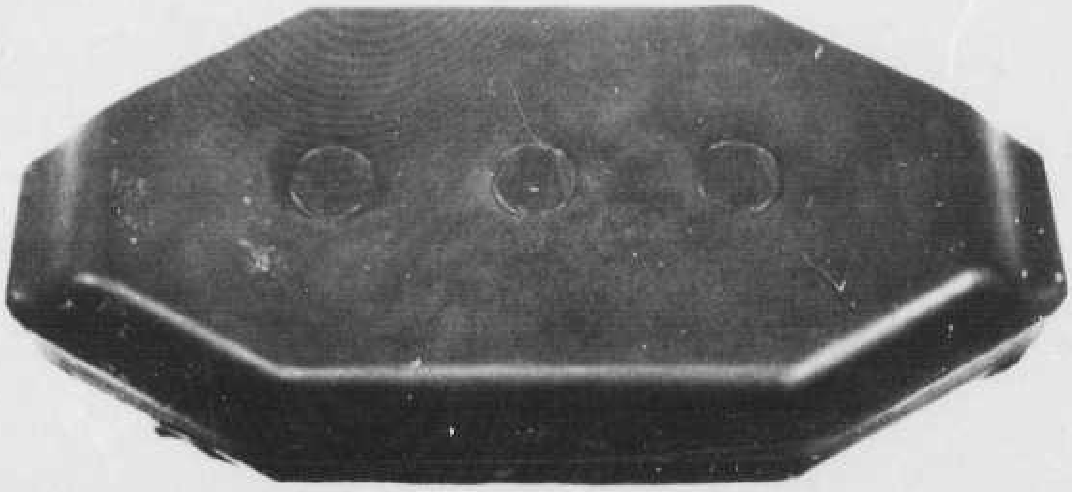


Trial 4-Three layers wire cloth positioned near bottom, horizontally



Trial 5-Six layers wire cloth distributed evenly, vertically

Figure 2



Conventional T142 Track Pad

T142 Track Pad with Rounded Contour

Conventional vs. Experimental T142 Track Pad

Figure 3

TABLE 1
COMPOUND FORMULATIONS (PARTS BY WEIGHT)

Compounding Ingredients	S152-1	S152-151	S152-155	S152-160	A50	A50-1	A50-2	A50-3	A50-6	S252	E59	E59-13	E59-14	E59-15	E59-16
SBR 1500	100	80	60	100	40	20		40	40						
Pale crepe		20	40		60	80	100	60				40	60	60	60
Ameripol 4713										137.5					
Ameripol SN 600									60						
EP syn 55											100	60	40	40	40
SAF black	45	45	45	45	45	45	45	45	45	70	45	45	45	45	45
Zinc oxide	4	4	4	4	4	4	4	4	4	4	3	3	3	3	3
Stearic acid	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Sulfur	2	2	2	2	2	2	2	2	2	2	0.2	0.2	0.2	0.2	0.2
Santocure	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	0.5	0.5	0.5	0.5	0.5
Di Cup 40C											5	5	5	5	5
Neozone D	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Santoflex AW				1.5											
U.O.P. 88	3	3	3	1.5	3	3	3	5	5	5					
Heliozone	1	1	1	1	1	1	1	1	1	1					
Dyphos				5										5	
Rio resin															5
Cure (mins. @Temp., °F):															
ASTM Test Pads	45@310	45@310	45@310	45@310	45@310	45@310	45@310	45@310	45@310	45@310	45@310	45@310	45@310	45@310	45@310
T142 Track Pads	75@320			75@320				75@320							

TABLE 1 (Continued)

Compounding Ingredients	S227-2	S227-5	S227-6	S227-21	S227-22	S227-23	S227-24	S227-25	S227-26	S227-27	S227-28	S227-29	A51	A51-1	A51-2	A51-3
Stereon 750	137.5	110	82.5	137.5	110	82.5	137.5	110	82.5	137.5	110	82.5	55	27.5		55
Pale crepe		20	40										60	80	100	
Bromobutyl					20	20		20	20		20	20				
EP syn 55						20			20			20				
Ameripol SN 600																60
SAF black	70	70	70	35	70	70				35	35	35	70	70	70	70
Hi Sil 233				20												
Neo novacite				15												
FEF black							70	70	70	35	35	35				
Zinc oxide	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Stearic acid	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Sulfur	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7
Santocure	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Neozone D	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Necton 60					7.5	15		7.5	15		7.5	15				
U.O.P. 88	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Heliozone	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
A 189				1												
Cure (mins. @Temp., °F):																
ASTM test pads	45@310	45@310	45@310	45@310	45@310	45@310	45@310	45@310	45@310	45@310	45@310	45@310	45@310	45@310	45@310	45@310
T142 track pads	75@320			75@320									75@320			

TABLE 1 (Continued)

Compounding Ingredients	S223-4	S223-10	S223-11	S223-29	S223-30	S223-31	S223-32	S223-33	S223-34	S223-35	S223-36	A52	A52-1	A52-2	A52-3
HYTRANS (SBR type)[1]	137.5	110	82.5	110	82.5	137.5	110	82.5	137.5	110	82.5	55	27.5		55
Pale crepe		20	40									60	80	100	
Bromobutyl				20	20		20	20		20	20				
EP syn 55					20			20			20				
Ameripol SN 600															60
SAF black	70	70	70	70	70				35	35	35	70	70	70	70
FEF black						70	70	70	35	35	35				
Zinc oxide	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Stearic acid	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Sulfur	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Santocure	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Neozone D	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Necton 60				7.5	15		7.5	15		7.5	15				
U.O.P. 88	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Heliozone	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Cure (mins. @Temp., oF):															
ASTM Test Pads	45@310	45@310	45@310	45@310	45@310	45@310	45@310	45@310	45@310	45@310	45@310	45@310	45@310	45@310	45@310
T142 Track Pads	75@320														

TABLE 1 (Continued)

Compounding Ingredients	B33-4	B33-5	B33-6	B33-7	B33-8	B33-9	B33-10	B33-11	B33-12	B33-13	B33-14	A53	A53-1	A53-2	A53-3
HYTRANS (Butadiene/isoprene type)[2]	137.5	110	82.5	110	82.5	137.5	110	82.5	137.5	110	82.5	55	27.5		55
Pale crepe		20	40									60	80	100	
Bromobutyl				20	20		20	20		20	20				
EP syn 55					20			20			20				
Ameripol SN 600															60
SAF black	70	70	70	70	70				35	35	35	70	70	70	70
Zinc oxide	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Stearic acid	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Sulfur	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Santocure	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Neozone D	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Necton 60				7.5	15		7.5	15		7.5	15				
U.O.P. 88	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Heliozone	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
FEF black						70	70	70	35	35	35				
Cure (mins. @Temp., °F):															
ASTM Test Pads	45@310	45@310	45@310	45@310	45@310	45@310	45@310	45@310	45@310	45@310	45@310	45@310	45@310	45@310	45@310
T142 Track Pads															

TABLE 1 (continued)

Compounding Ingredients	S212-2	S212-5	S212-6	S212-7	A54	A54-1	A54-2	A54-3	S152-166	S152-167	S152-168	S152-169	S152-170	S152-171
Philprene 1609	101.5	81.2	60.9	101.5	40.6	20.3		40.6						
Cis-4 1350[3] or Cis-4 1351[4]	64.5	51.6	38.7	64.5	25.8	12.9		25.8						
Pale Crepe		20	40		60	60	100							
Ameripol SN 600								60						
SBR 1500									100	100	100	100	100	100
SAF Black		14	28		42	56	70	42	25	25	25	25	25	25
Hi Sil 233									20	20	20	5	5	5
Neo Novacite												15	15	15
Zinc oxide	3	3	3	3	3	3	3	3	4	4	4	4	4	4
Stearic acid	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Neozone D									1	1	1	1	1	1
Sulfur	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Santocure	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Thermoflex A	1	1	1	1	1	1	1	1						
Santoflex AW	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5						
Piccopale 100	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5						
A169										0.5	1		0.5	1
U.O.P. 88	5	5	5	5	5	5	5	5	3	3	3	3	3	3
Heliozone	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Dyphos				5										
Cure (mins. @ Temp., °F):														
ASTM Test Pads	45@310	45@310	45@310	45@310	45@310	45@310	45@310	45@310	45@310	45@310	45@310	45@310	45@310	45@310
T142 Track Pads	75@320			75@320	75@320									

[1] 85/15 Butadiene/Styrene - 37.5 parts oil extended

[2] 90/10 Butadiene/Isoprene - 37.5 parts oil extended

[3] Cis-4 Polybutadiene masterbatch (100 parts Cis-4 1203, 80 parts Philblack I and 35 parts Philrich 5)

[4] Cis-4 Polybutadiene masterbatch (100 parts Cis-4 1203, 90 parts Philblack I and 50 parts Philrich 5)

Note: Cis-4 1350 or Cis-4 1351 may be used interchangeably in blends with Philprene 1609 without affecting physical properties of the vulcanizates

TABLE 2

RESISTANCE TO HEAT BUILDUP OF SBR 1500 VULCANIZATES CONTAINING WIRE CLOTH

SPECIMEN DESCRIPTION	TIME TO GO FROM 100° to 200°F, MINUTES, 0.25" THROW, 600 lb. LOAD, FIRESTONE FLEXOMETER	EVIDENCE OF TEARING OR DELAMINATION
Trial 1-No wire cloth, control	25.3	None
Trial 2-Six layers wire cloth distributed evenly, horizontally	104.0	Very slight tearing of rubber around wire cloth
Trial 3-Three layers wire cloth positioned in center, horizontally	28.1	None
Trial 4-Three layers wire cloth positioned near bottom, horizontally	23.4	None
Trial 5-Six layers wire cloth distributed evenly, vertically	13.0	Significant tearing and delamination of rubber around wire cloth

TABLE 3

EVALUATION OF POTENTIAL HEAT STABILIZERS IN RESEARCH DIRECTORATE SBR 1500 CONTROL COMPOUND (S152-1)

Physical Properties	S152-1 (Control)	S152-156 5 parts/ 100 rhc Graphite	S152-160 5 parts/ 100 rhc Dyphos	S152-161 5 parts/ 100 rhc Dythal	S152-165 3 parts/ 100 rhc Dythal	S152-162 5 parts/ 100 rhc Antimony Trioxide	S152-163 5 parts/ 100 rnc Aluminum Oxide
Tested at Ambient:							
Tensile, psi	4520	3950	4190	4050	4505	4625	3720
Modulus @100% Elongation, psi	390	415	320	500	410	440	380
Modulus @200% Elongation, psi	980	1050	755	1450	1095	770	800
Modulus @300% Elongation, psi	1915	2065	1630	2750	2160	1540	1635
Ultimate Elongation, %	530	490	570	400	490	610	500
Hardness, Shore A	65	67	66	70	69	65	67
Tested at 300°F:							
Tensile, psi	950(-79)*	760(-81)	1135(-73)	1095(-73)	1085(-76)	1080(-77)	795(-79)
Modulus @100% Elongation, psi	310(-21)	300(-28)	275(-14)	420(-16)	370(-10)	235(-47)	300(-21)
Modulus @200% Elongation, psi	715(-27)	710(-32)	545(-28)	1070(-25)	855(-22)	565(-27)	620(-23)
Modulus @300% Elongation, psi	--	--	1045(-36)	--	--	1035(-33)	--
Ultimate, Elongation, %	250(-53)	220(-55)	320(-44)	210(-48)	230(-53)	320(-48)	230(-54)
Aged 70 Hours at 212°F:							
Tensile, psi	4160(-8)	3205(-19)	3665(-13)	3900(-4)	4000(-11)	3930(-15)	3355(-10)
Modulus @100% Elongation, psi	710(+82)	820(+98)	730(+128)	945(+89)	755(+84)	505(+15)	565(+49)
Modulus @200 % Elongation, psi	1755(+79)	1870(+78)	1605(+39)	2305(+59)	2035(+86)	1445(+88)	1605(+101)
Modulus @300 % Elongation, psi	3130(+63)	3205(+55)	3025(+86)	3900(+42)	3575(+65)	2770(+80)	2835(+71)
Ultimate Elongation, %	380(-28)	300(-39)	370(-35)	300(-25)	340(-31)	390(-36)	340(-32)
Hardness, Shore A	74(+14)	76(+13)	74(+12)	75(+7)	74(+7)	75(+15)	73(+9)
Tear, Die C, ambient, pi	215	230	235	210	195	240	225
Tear, Die C, at 250°F, pi	115	100	190	100	110	135	125
Firestone Flexometer, 0.25 inch throw, 600 pound load, time to go from 100 - 200°F, minutes	23.5	25.8	13.2	67.1	22.3	13.5	18.4
Specific Gravity	1.13	1.15	1.16	1.17	1.16	1.17	1.16

*Values in parentheses are percent change from original value

TABLE 3 (Continued)

Physical Properties	S152-164 5 parts/ 100 rhc Cadmium Oxide	S152-177 2 parts/ 100 rhc Cadmium Oxide	S152-172 5 parts/ 100 rhc Ceric Oxide	S152-173 5 parts/ 100 rhc Chromium Trioxide	S152-174 5 parts/ 100 rhc A1[illegible]9	S152-181 2 parts/ 100 rhc A189	S152-175 5 parts/ 100 rhc Ferric Oxide
Tested at ambient:							
Tensile, psi	3415	3675	4630	3360	3600	4495	4470
Modulus @100% Elongation, psi	680	425	410	370	225	435	375
Modulus @200% Elongation, psi	2110	1270	[illegible]	925	460	1080	1105
Modulus @300% Elongation, psi	--	2495	1765	1840	1090	2060	1795
Ultimate Elongation, %	290	400	570	430	660	530	560
Hardness, Shore A	72	[illegible]	66	67	65	67	65
Tested at 300°F:							
Tensile, psi	[illegible]0(-74)*	940(-74)	990(-79)	750(-75)	930(-74)	1300(-71)	1200(-73)
Modulus @100% Elongation, psi	645(-5)	395(-7)	235(-43)	305(-19)	235(+4)	320(-26)	290(-23)
Modulus @200% Elongation, psi	--	940(-26)	660(-26)	655(-29)	490(+7)	790(-27)	670(-39)
Modulus @300% Elongation, psi	--	--	--	--	860(-21)	1300(-37)	--
Ultimate Elongation, %	130(-55)	200(-50)	280(-51)	210(-51)	320(-52)	300(-43)	290(-48)
Aged 70 Hours at 212°F:							
Tensile, psi	3530(+3)	3665(0)	4170(-10)	2465(-27)	3460(-4)	4145(-8)	4325(-3)
Modulus @100% Elongation, psi	1030(+51)	830(+95)	635(+55)	675(+82)	540(+140)	620(+43)	540(+44)
Modulus @200% Elongation, psi	2735(+30)	2110(+66)	1805(+104)	1830(+98)	1285(+179)	1760(+63)	1600(+45)
Modulus @300% Elongation, psi	--	3665(+47)	3245(+84)	--	2365(+117)	3000(+46)	3010(+68)
Ultimate Elongation, %	250(-14)	300(-25)	390(-32)	250(-42)	420(-36)	390(-26)	400(-30)
Hardness, Shore A	78(+8)	75(+10)	72(+9)	75(+12)	73(+12)	73(+9)	73(+12)
Tear, Die C, ambient, pi	170	205	230	215	240	230	220
Tear, Die C, at 250°F, pi	35	95	120	120	200	115	125
Firestone Flexometer, 0.25 inch throw, 600 pound load, time to go from 100 - 200°F, minutes	+100**	43.5	18.5	18.3	11.9	38.5	16.5
Specific Gravity	1.17	1.18	1.17	1.16	1.14	1.14	1.17

*Values in parentheses are percent change from original value
**Temperature had not reached 200°F after 100 minutes of testing

TABLE 3 (Continued)

Physical Properties	S152-176 5 parts/ 100 rhc Ferric Phosphate(ins)	S152-178 5 parts/ 100 rhc Manganese Dioxide	S152-179 5 parts/ 100 rhc Nickel Oxide	S152-180 5 parts/ 100 rhc Zirconium Oxide	S152-182 5 parts/ 100 rhc Rio Resin	S152-185 3 parts/ 100 rhc Aluminum Hydroxide
Tested at ambient:						
Tensile, psi	4000	4450	4615	4625	4720	4095
Modulus @100% Elongation, psi	440	370	350	335	360	375
Modulus @200% Elongation, psi	1110	855	835	800	665	940
Modulus @300% Elongation, psi	2120	1810	1725	1645	1280	2025
Ultimate Elongation, %	480	550	570	570	680	480
Hardness, Shore A	67	66	66	66	65	67
Tested at 300°F:						
Tensile, psi	1060(-74)*	1150(-74)	1110(-78)	1205(-76)	1165(-75)	610(-85)
Modulus @100% Elongation, psi	370(-16)	280(-24)	285(-19)	315(-6)	250(-31)	330(-12)
Modulus @200% Elongation, psi	765(-31)	565(-34)	620(-26)	625(-22)	505(-24)	---
Modulus @300% Elongation, psi	--	1060(-41)	1110(-36)	1205(-27)	935(-27)	---
Ultimate Elongation, %	250(-48)	320(-42)	300(-47)	300(-47)	350(-49)	160(-67)
Aged 70 Hours at 212°F:						
Tensile, psi	3690(-8)	920(-79)	4235(-8)	3955(-14)	3945(-16)	3765(-8)
Modulus @100% Elongation, psi	765(+74)	---	610(+74)	605(+81)	475(+32)	540(+44)
Modulus @200% Elongation, psi	1870(+68)	---	1705(+104)	1535(+92)	1210(+82)	1555(+65)
Modulus @300% Elongation, psi	3330(+57)	---	2880(+67)	2820(+71)	2210(+73)	3070(+51)
Ultimate Elongation, %	320(-33)	60(-89)	410(-28)	400(-30)	480(-29)	350(-27)
Hardness, Shore A	75(+12)	77(+17)	71(+8)	71(+8)	70(+8)	74(+10)
Tear, Die C, Ambient, pi	220	230	225	225	255	220
Tear, Die C, at 250°F, pi	105	170	120	135	190	90
Firestone Flexometer, 0.25 inch throw, 600 pound load, time to go from 100 - 200°F, minutes	21.4	19.6	22.8	21.7	15.0	33.9
Specific Gravity	1.16	1.16	1.17	1.17	1.14	1.14

*Values in parentheses are percent change from original value

TABLE 4

EVALUATION OF POTENTIAL HEAT STABILIZERS IN STEREON 750 (S227-2)

Physical Properties	S227-2 (Control)	S227-7 5 parts/ 100 rhc Dyphos	S227-8 5 parts/ 100 rhc Dythal	S227-9 5 parts/ 100 rhc Cadmium Oxide	S227-10 3 parts/ 100 rhc Cadmium Oxide	S227-15 1 part/ 100 rhc Cadmium Oxide
Tested at Ambient:						
Tensile, psi	2910	2920	2715	2620	2730	2725
Modulus @100% Elongation, psi	225	225	295	385	340	270
Modulus @200% Elongation, psi	410	400	780	915	810	570
Modulus @300% Elongation, psi	775	810	1610	1830	1620	1095
Ultimate Elongation, %	720	670	450	400	430	570
Hardness, Shore A	58	58	60	64	62	58
Tested at 300°F:						
Tensile, psi	905 (-69)*	920 (-68)	920 (-66)	845 (-68)	925 (-66)	905 (-67)
Modulus @100% Elongation, psi	145 (-36)	135 (-40)	235 (-20)	270 (-30)	300 (-12)	190 (-30)
Modulus @200% Elongation, psi	290 (-29)	320 (-20)	550 (-29)	680 (-26)	650 (-20)	474 (-17)
Modulus @300% Elongation, psi	475 (-39)	550 (-32)	--	--	--	905 (-17)
Ultimate Elongation, %	520 (-28)	410 (-39)	270 (-40)	260 (-35)	260 (-40)	300 (-47)
Aged 70 hours at 212°F:						
Tensile, psi	2540 (-13)	2730 (-7)	2720 (0)	2565 (-2)	2690 (-1)	2465 (-10)
Modulus @ 100% Elongation, psi	335 (+49)	375 (+67)	505 (+71)	470 (+22)	450 (+32)	325 (+20)
Modulus @ 200% Elongation, psi	695 (+70)	845 (+111)	1165 (+49)	1150 (+26)	1095 (+35)	820 (+44)
Modulus @ 300% Elongation, psi	1225 (+58)	1555 (+92)	2035 (+26)	2070 (+13)	2025 (+25)	1535 (+40)
Ultimate Elongation, %	560 (-22)	520 (-22)	420 (-7)	360 (-10)	410 (-5)	430 (-25)
Hardness, Shore A	65 (+12)	66 (+14)	68 (+13)	69 (+8)	69 (+11)	65 (+12)
Tear, Die C, ambient, pi	215	200	185	175	165	190
Tear, Die C, at 250°F, pi	195	170	120	135	105	170
Firestone Flexometer, 0.25 inch throw, 600 pound load, time to go from 100-200°F, minutes	7.7	7.7	17.3	21.2	22.1	10.7
Specific gravity	1.14	1.16	1.15	1.16	1.15	1.14

*Values in parentheses are percent change from original value

TABLE 4 (Continued)

Physical Properties	S227-11 5 parts/ 100 rhc A189	S227-12 2 parts/ 100 rhc A189	S227-13 5 parts/ 100 rhc Manganese Dioxide	S227-14 5 parts/ 100 rhc Rio Resin	S227-22 5 parts/ 100 rhc Aluminum Hydroxide	S227-23 3 parts/ 100 rhc Aluminum Hydroxide
Tested at Ambient:						
Tensile, psi	2665	3160	2810	2845	2315	2430
Modulus @100% Elongation, psi	225	245	240	135	145	180
Modulus @200% Elongation, psi	460	465	475	225	295	225
Modulus @300% Elongation, psi	855	990	980	495	490	455
Ultimate Elongation, %	700	660	600	840	770	790
Hardness, Shore A	58	58	60	55	55	55
Tested at 300°F:						
Tensile, psi	890 (-67)*	890 (-72)	950 (-66)	910 (-68)	680 (-71)	705 (-61)
Modulus @100% Elongation, psi	180 (-20)	190 (-22)	190 (-21)	95 (-30)	95 (-34)	95 (-47)
Modulus @200% Elongation, psi	355 (-23)	375 (-19)	380 (-20)	240 (+7)	195 (-34)	200 (-11)
Modulus @300% Elongation, psi	580 (-32)	585 (-41)	615 (-37)	385 (-22)	340 (-30)	345 (-24)
Ultimate Elongation, %	400 (-43)	400 (-39)	400 (-33)	500 (-40)	550 (-29)	550 (-30)
Aged 70 hours at 212°F:						
Tensile, psi	2230 (-16)	2500 (-21)	1990 (-29)	2590 (-9)	2315 (0)	2410 (-1)
Modulus @ 100% Elongation, psi	325 (+44)	335 (+37)	495 (+106)	275 (+104)	240 (+66)	240 (+33)
Modulus @ 200% Elongation, psi	520 (+13)	715 (+54)	1135 (+139)	475 (+111)	560 (+90)	580 (+158)
Modulus @ 300% Elongation, psi	975 (+14)	1310 (+32)	1895 (+93)	910 (+86)	1090 (+123)	1060 (+133)
Ultimate Elongation, %	630 (-10)	510 (-23)	320 (-47)	650 (-23)	560 (-27)	600 (-24)
Hardness, Shore A	65 (+12)	65 (+12)	68 (+13)	64 (+16)	65 (+18)	63 (+15)
Tear, Die C, ambient, pi	220	195	195	215	190	190
Tear, Die C, at 250°F, pi	185	215	200	205	175	160
Firestone Flexometer, 0.25 inch throw, 600 pound load, time to go from 100-200°F, minutes	8.4	10.4	11.3	6.3	5.5	5.5
Specific Gravity	1.14	1.15	1.16	1.14	1.14	1.14

*Values in parentheses are percent change from original value

TABLE 5

EVALUATION OF POTENTIAL HEAT STABILIZERS IN PHILPRENE 1609/CIS-4 1350 BLEND (S212-2)

Physical Properties	S212-2 (Control)	S212-7 5 parts/ 100 rhc Dyphos	S212-14 3 parts/ 100 rhc Dyphos	S212-8 5 parts/ 100 rhc Dythal	S212-9 5 parts/ 100 rhc Cadmium Oxide	S212-10 3 parts/ 100 rhc Cadmium Oxide	S212-11 1 part/100 rhc Cadmium Oxide
Tested at Ambient:							
Tensile, psi	2700	2635	3025	2585	1740	2275	2715
Modulus @100% Elongation, psi	295	200	200	245	465	320	240
Modulus @200% Elongation, psi	585	400	395	635	1165	910	480
Modulus @300% Elongation, psi	1120	800	830	1465	--	1695	1150
Ultimate Elongation, %	580	650	670	450	260	370	550
Hardness, Shore A	59	58	56	62	65	62	59
Tested at 300°F:							
Tensile, psi	930(-66)*	800(-70)	975(-68)	870(-66)	500(-71)	780(-66)	770(-72)
Modulus @100% Elongation, psi	235(-20)	150(-25)	145(-28)	255(+4)	450(-3)	340(+6)	205(-15)
Modulus @200% Elongation, psi	480(-18)	350(-13)	390(-1)	665(+5)	--	--	510(+6)
Modulus @300% Elongation, psi	930(-17)	550(-31)	640(-23)	--	--	--	--
Ultimate Elongation, %	300(-48)	400(-38)	410(-39)	220(-51)	120(-54)	170(-54)	260(-53)
Aged 70 Hours at 212°F:							
Tensile, psi	2590(-4)	2685(+2)	2825(-7)	2250(-13)	1900(+9)	2530(+11)	2600(-4)
Modulus @100% Elongation, psi	375(+27)	395(+98)	355(+78)	455(+86)	580(+25)	440(+38)	335(+40)
Modulus @200% Elongation,psi	965(+65)	890(+123)	900(+13)	1165(+83)	1400(+20)	1400(+54)	1025(+114)
Modulus @300% Elongation,psi	1695(+51)	1580(+98)	1640(+98)	2250(+54)	--	2300(+36)	1830(+58)
Ultimate Elongation,%	430(-26)	480(-26)	450(-33)	300(-33)	240(-8)	350(-5)	410(-25)
Hardness, Shore A	65(+10)	67(+16)	65(+16)	69(+11)	70(+8)	69(+11)	65(+10)
Tear, Die C, ambient, pi	205	200	220	180	165	175	195
Tear, Die C, at 250°F, pi	150	205	205	110	80	95	110
Firestone Flexometer, 0.25 inch throw, 600 pound load, time to go from 100-200°F, mins.	14.3	9.2	10.0	21.5	+100**	83	18.0
Specific Gravity	1.14	1.15	1.15	1.15	1.15	1.15	1.14

*Values in parentheses are percent change from original value

**Temperature had not reached 200°F after 100 minutes of testing

TABLE 5 (Continued)

Physical Properties	S212-12 5 parts/ 100 rhc A189	S212-13 2 parts/ 100 rhc A189	S212-15 5 parts/ 100 rhc Manganese Dioxide	S212-16 5 parts/ 100 rhc Rio Resin	S212-17 5 parts/ 100 rhc Aluminum Hydroxide
Tested at Ambient:					
Tensile, psi	2665	2730	2965	2990	3200
Modulus @100% Elongation, psi	220	195	235	195	190
Modulus @200% Elongation, psi	440	535	520	440	375
Modulus @300% Elongation, psi	800	1025	1130	925	755
Ultimate Elongation, %	660	570	550	610	730
Hardness, Shore A	52	57	61	59	56
Tested at 300°F:					
Tensile, psi	785(-71)*	875(-68)	905(-69)	810(-73)	865(-73)
Modulus @100% Elongation, psi	190(-14)	240(+23)	235(0)	205(+5)	190(0)
Modulus @200% Elongation, psi	425(-4)	480(-10)	505(-3)	455(+3)	380(+1)
Modulus @300% Elongation, psi	740(-8)	840(-18)	800(-29)	760(-18)	615(-19)
Ultimate Elongation	310(-53)	310(-46)	310(-44)	310(-49)	400(-45)
Aged 70 Hours at 212°F:					
Tensile, psi	2375(-11)	2795(+2)	1495(-50)	2685(-10)	2650(-17)
Modulus @100% Elongation, psi	275(+25)	350(-79)	635(+170)	340(+74)	295(+55)
Modulus @200% Elongation, psi	725(+65)	770(+44)	1495(+188)	840(+91)	685(+83)
Modulus @300% Elongation, psi	1245(+56)	1495(+46)	--	1700(+84)	1385(+83)
Ultimate Elongation,%	500(-24)	480(-16)	200(-64)	420(-31)	500(-32)
Hardness, Shore A	63(+21)	64(+12)	74(+21)	65(+10)	63(+13)
Tear, Die C, ambient, pi	200	210	205	210	220
Tear, Die C, at 250°F, pi	180	160	200	135	150
Firestone Flexometer, 0.25 inch throw, 600 pound load, time to go from 100-200°F, mins.	11.1	11.4	14.3	13.3	10.8
Specific Gravity	1.13	1.13	1.16	1.15	1.14

*Values in parentheses are percent change from original value

TABLE 6

EVALUATION OF POTENTIAL HEAT STABILIZERS IN HYTRANS 1227-289-1 (S223-4)

Physical Properties	S223-4 (Control)	S223-12 5 parts/ 100 rhc Dyphos	S223-13 3 parts/ 100 rhc Dyphos	S223-14 5 parts/ 100 rhc Dythal	S223-15 5 parts/ 100 rhc Cadmium Oxide	S223-16 3 parts/ 100 rhc Cadmium Oxide	S223-17 1 part/ 100 rhc Cadmium Oxide
Tested at Ambient:							
Tensile, psi	3230	3190	3010	3270	3095	2990	2830
Modulus @100% Elongation, psi	145	150	135	255	340	195	245
Modulus @200% Elongation, psi	335	350	325	700	830	640	490
Modulus @300% Elongation, psi	690	850	765	1465	1805	1410	1025
Ultimate Elongation, %	720	650	630	520	450	500	570
Hardness, Shore A	58	58	58	63	64	63	59
Tested at 300°F:							
Tensile, psi	920(-72)*	980(-69)	1000(-67)	950(-71)	930(-70)	840(-72)	845(-70)
Modulus @100% Elongation, psi	140(-3)	195(+30)	185(+37)	245(-4)	355(+4)	245(+26)	205(-16)
Modulus @200% Elongation, psi	320(-4)	340(-3)	330(+2)	500(-29)	760(-8)	550(-14)	405(-17)
Modulus @300% Elongation, psi	460(-33)	595(-30)	550(-28)	950(-35)	--	--	710(-31)
Ultimate Elongation, psi	490(-32)	430(-34)	450(-29)	300(-42)	210(-53)	280(-44)	330(-42)
Aged 70 Hours at 212°F:							
Tensile, psi	3135(-3)	2865(-10)	3070(-2)	3035(-7)	3085(0)	3060(+2)	2795(-1)
Modulus @100% Elongation, psi	320(+121)	395(+163)	325(+141)	480(+88)	530(+56)	370(+90)	355(+45)
Modulus @200% Elongation, psi	710(+112)	840(+140)	790(+143)	1025(+46)	1175(+42)	965(+51)	910(+86)
Modulus @300% Elongation, psi	1455(+109)	1680(+98)	1645(+115)	2070(+41)	2070(+15)	1955(+39)	1770(+73)
Ultimate Elongation, %	550(-24)	460(-29)	500(-21)	420(-19)	410(-9)	430(-14)	430(-25)
Hardness, Shore A	67(+16)	68(+17)	68(+17)	70(+11)	68(+6)	69(+10)	69(+17)
Tear, Die C, ambient, pi	200	195	195	190	175	185	190
Tear, Die C, at 250°F, pi	235	170	195	175	110	140	170
Firestone Flexometer, 0.25 inch throw, 600 pound load, time to go from 100-200°F, mins.	8.5	10.5	10.0	14.1	21.3	17.6	12.5
Specific Gravity	1.14	1.16	1.15	1.16	1.16	1.16	1.17

*Values in parentheses are percent change from original value

TABLE 6 (Continued)

Physical Properties	S223-18 5 parts/ 100 rhc A189	S223-19 2 parts/ 100 rhc A189	S223-20 5 parts/ 100 rhc Manganese Dioxide	S223-21 5 parts/ 100 rhc Rio Resin	S223-22 5 parts/ 100 rhc Aluminum Hydroxide
Tested at Ambient:					
Tensile, psi	2235	3075	2855	2960	2945
Modulus @100% Elongation, psi	225	245	205	105	95
Modulus @200% Elongation, psi	450	490	445	210	240
Modulus @300% Elongation, psi	885	975	940	475	625
Ultimate Elongation, %	590	640	600	770	660
Hardness, Shore A	60	60	59	54	58
Tested at 300°F:					
Tensile, psi	700(+4)*	855(-72)	840(-71)	840(-72)	830(-72)
Modulus @100% Elongation, psi	190(-16)	190(-22)	195(-5)	100(-5)	145(+53)
Modulus @200% Elongation, psi	370(-18)	380(-22)	340(-24)	200(-5)	340(-42)
Modulus @300% Elongation, psi	560(-38)	570(-42)	545(-42)	345(-27)	570(-9)
Ultimate Elongation, %	350(-41)	400(-38)	400(-33)	550(-29)	400(-39)
Aged 70 Hours at 212°F:					
Tensile, psi	2320(+4)	2960(-4)	2535(-11)	2885(-3)	2810(-5)
Modulus @100% Elongation, psi	320(+42)	305(+24)	440(+115)	255(+143)	240(+153)
Modulus @200% Elongation, psi	680(+51)	810(+65)	1170(+163)	580(+176)	580(+142)
Modulus @300% Elongation, psi	1350(+53)	1505(+54)	1830(+95)	1165(+145)	1315(+110)
Ultimate Elongation, %	460(-22)	510(-20)	360(-40)	570(-26)	500(-24)
Hardness, Shore A	68(+13)	67(+12)	70(+19)	67(+24)	67(+16)
Tear, Die C, ambient, pi	200	200	190	210	195
Tear, Die C, at 250°F, pi	195	195	180	220	195
Firestone Flexometer, 0.25 inch throw, 600 pound load, time to go from 100-200°F, mins.	9.7	11.6	14.1	7.2	9.2
Specific Gravity	1.17	1.17	1.17	1.17	1.18

*Values in parentheses are percent change from original value

TABLE 7

EVALUATION OF SILICA/BLACK AND SILICA/GROUND QUARTZ/BLACK REINFORCING COMBINATIONS IN SBR 1500

Physical Properties	S152-1 (Control)	S152-166 Hi Sil 233/ Statex 160	S152-167 Hi Sil 233/ Statex 160/ A189 (0.5)	S152-168 Hi Sil 233/ Statex 160 A189 (1.0)	S152-169 Hi Sil 233/ Neo Novacite/ Statex 160	S152-170 Hi Sil 233/ Neo Novacite/ Statex 160/ A189 (0.5)	S152-171 Hi-Sil 233/ Neo Novacite/ Statex 160/ A189 (1.0)
Tested at ambient:							
Tensile, psi	4520	3495	3860	4095	3470	3585	3690
Modulus @100% Elongation, psi	390	330	380	435	280	330	355
Modulus @200% Elongation, psi	980	590	760	900	480	600	760
Modulus @300% Elongation, psi	1915	955	1335	1665	865	1080	1265
Ultimate Elongation, %	530	670	620	580	620	600	520
Hardness, Shore A	65	63	63	65	59	60	61
Tested at 300°F:							
Tensile, psi	950 (-79)*	735 (-79)	900 (-77)	920 (-78)	470 (-86)	425 (-88)	540 (-85)
Modulus @100% Elongation, psi	310 (-21)	225 (-32)	315 (-17)	350 (-20)	225 (-20)	290 (-12)	320 (-10)
Modulus @200% Elongation, psi	715 (-27)	425 (-28)	560 (-26)	695 (-23)	380 (-21)	--	--
Modulus @300% Elongation, psi	--	625 (-35)	900 (-33)	--	--	--	--
Ultimate Elongation, %	250 (-53)	340 (-49)	300 (-52)	260 (-55)	230 (-63)	190 (-68)	180 (-65)
Aged 70 Hours @212°F:							
Tensile, psi	4160 (-8)	3045 (-13)	3425 (-11)	3550 (-13)	3170 (-9)	2695 (-25)	2890 (-22)
Modulus @100% Elongation, psi	710 (+82)	570 (+72)	600 (+58)	700 (+61)	390 (+39)	510 (-55)	540 (+52)
Modulus @200% Elongation, psi	1755 (+79)	1120 (+90)	1410 (+86)	1580 (+76)	825 (+72)	975 (+63)	1185 (+56)
Modulus @300% Elongation, psi	3130 (+63)	1875 (+96)	2380 (+78)	2800 (+68)	1525 (+76)	1740 (+61)	2125 (+68)
Ultimate Elongation, %	380 (-28)	430 (-36)	410 (-34)	380 (-34)	470 (-24)	400 (-33)	380 (-27)
Hardness, Shore A	74 (+14)	73 (+16)	74 (+17)	74 (+14)	65 (+10)	66 (+10)	68 (+11)
Tear, Die C, ambient, pi	215	235	260	240	165	180	185
Tear, Die C, at 250°F, pi	115	100	110	105	60	65	60
Firestone Flexometer, 0.25 inch throw, 600 pound load, time to go from 100 - 200°F, minutes	23.5	11.3	16.3	24.0	26.5	41.3	+100**
Specific Gravity	1.13	1.15	1.15	1.15	1.17	1.17	1.17

*Values in parentheses are percent change from original value
**Temperature had still not reached 200°F after 100 minutes of testing

TABLE 8
EVALUATION OF SBR 1500/PALE CREPE BLENDS

Physical Properties	S152-1 100 SBR 1500	S152-154 80/20 SBR 1500/ Pale Crepe	S152-155 60/40 SBR 1500/ Pale Crepe	A50 40/60 SBR 1500/ Pale Crepe	A50-1 20/80 SBR 1500/ Pale Crepe	A50-2 100 Pale Crepe
Tested at Ambient:						
Tensile, psi	4100	4000	3700	3910	4000	3290
Modulus @100% Elongation, psi	375	335	350	370	360	275
Modulus @200% Elongation, psi	845	890	900	920	875	675
Modulus @300% Elongation, psi	1820	1825	1850	1735	1760	1315
Ultimate Elongation, %	510	510	480	520	550	550
Hardness, Shore A	66	65	66	66	65	61
Tested at 300°F:						
Tensile, psi	980 (-76)*	1035 (-74)	995 (-73)	1325 (-66)	1740 (-57)	1820 (-45)
Modulus @100% Elongation, psi	310 (-17)	320 (-4)	300 (-14)	280 (-24)	275 (-24)	205 (-25)
Modulus @200% Elongation, psi	710 (-16)	660 (-26)	715 (-21)	560 (-39)	565 (-35)	360 (-47)
Modulus @300% Elongation, psi	--	--	--	990 (-43)	1000 (-43)	570 (-57)
Ultimate Elongation, %	280 (-45)	290 (-43)	280 (-42)	390 (-25)	450 (-18)	520 (-5)
Tested at 400°F:						
Tensile, psi	410 (-90)	500 (-88)	445 (-88)	525 (-87)	470 (-88)	305 (-91)
Modulus @100% Elongation, psi	225 (-40)	200 (-40)	200 (-43)	190 (-49)	170 (-53)	100 (-64)
Modulus @200% Elongation, psi	410 (-52)	445 (-50)	395 (-56)	425 (-54)	260 (-70)	200 (-79)
Modulus @300% Elongation, psi	--	--	--	525 (-69)	380 (-78)	250 (-81)
Ultimate Elongation, %	200 (-61)	220 (-57)	230 (-52)	310 (-40)	350 (-36)	360 (-35)
Tear, Die C, ambient, pi	230	220	200	410	505	400
Tear, Die C, at 250°F, pi	110	100	115	245	285	215
Tear, Die C, at 300°F, pi	95	100	110	165	195	190
ASTM D1043, T200, °F	-26	-34	-33	-35	-41	-58
Abrasion Resistance, Du Pont Abrader, Volume Loss after 25 min., cc, (% of reference compound S152-1)	1.1109 (100)	1.1351 (98)	1.1404 (97)	0.1360 (817)	0.1255 (885)	0.2781 (399)
Crack Growth, DeMattia Tester, 50,000 cycles, 32nds of an inch	23	22	21	12	4	0
Time to first crack, 50± 5 pphm Ozone @100± 2°F, 30 days, Bent Loop Specimen	Crack Free	Crack Free	Crack Free	4 Hours	4 Hours	2 Hours
Specific Gravity	1.15	1.14	1.14	1.13	1.12	1.10

*Values in parentheses are percent change from original values

TABLE 9
EVALUATION OF STEREON 750/PALE CREPE BLENDS

Physical Properties	S227-2 100 Stereon 750	S227-5 110/20 Stereon 750/ Pale Crepe	S227-6 82.5/40 Stereon 750/ Pale Crepe	A51 55/60 Stereon 750/ Pale Crepe	A51-1 27.5/80 Stereon 750/ Pale Crepe	A51-2 100 Pale Crepe
Tested at Ambient:						
Tensile, psi	2810	2825	3000	2825	2975	2190
Modulus @100% Elongation, psi	190	275	240	320	325	290
Modulus @200% Elongation, psi	335	435	525	590	745	475
Modulus @300% Elongation, psi	665	845	1050	1180	1505	1315
Ultimate Elongation, %	730	670	610	580	520	450
Hardness, Shore A	56	60	62	66	67	66
Tested at 300°F:						
Tensile, psi	855 (-69)*	850 (-70)	830 (-72)	840 (-70)	820 (-72)	790 (-64)
Modulus @100% Elongation, psi	145 (-24)	190 (-31)	185 (-23)	185 (-42)	225 (-31)	185 (-36)
Modulus @200% Elongation, psi	285 (-15)	330 (-24)	370 (-30)	370 (-37)	450 (-40)	325 (-52)
Modulus @300% Elongation, psi	460 (-31)	520 (-31)	550 (-48)	610 (-48)	680 (-55)	445 (-66)
Ultimate Elongation, %	500 (-32)	480 (-28)	480 (-21)	470 (-19)	490 (-6)	490 (+9)
Tested at 400°F:						
Tensile, psi	425 (-85)	420 (-85)	415 (-86)	330 (-88)	230 (-92)	140 (-94)
Modulus @100% Elongation, psi	95 (-50)	140 (-49)	135 (-44)	140 (-56)	140 (-57)	90 (-69)
Modulus @200% Elongation, psi	190 (-43)	235 (-46)	230 (-56)	235 (-60)	--	140 (-79)
Modulus @300% Elongation, psi	285 (-59)	--	--	330 (-72)	--	--
Ultimate Elongation, %	420 (-42)	420 (-37)	320 (-47)	300 (-48)	290 (-44)	200 (-56)
Tear, Die C, ambient, pi	225	230	250	285	450	120
Tear, Die C, at 250°F, pi	175	190	220	235	275	250
Tear, Die C, at 300°F, pi	150	150	170	170	200	185
ASTM D1043, T200, °F	-58	-46	-43	-45	-40	-41
Abrasion Resistance, Du Pont Abrader, Volume Loss after 25 min., cc, (% of reference compound S227-2)	0.1765 (100)	0.1513 (117)	0.1613 (109)	0.1796 (98)	0.2567 (69)	0.5011 (35)
Crack Growth, DeMattia Tester, 50,000 cycles, 32nds of an inch	18	22	18	6	2	0
Time to first crack, 50± 5 pphm Ozone @100± 2°F, 30 days, Bent Loop Specimen	Crack Free	4 Hours	4 Hours	4 Hours	4 Hours	2 Hours
Specific Gravity	1.14	1.15	1.14	1.14	1.15	1.15

*Values in parentheses are percent change from original values

TABLE 10
EVALUATION OF HYTRANS 1227-289-1*/PALE CREPE BLENDS

Physical Properties	S223-4 100 HYTRANS	S223-10 110/20 HYTRANS/ Pale Crepe	S223-11 82.5/40 HYTRANS/ Pale Crepe	A52 55/60 HYTRANS/ Pale Crepe	A52-1 27.5/80 HYTRANS/ Pale Crepe	A52-2 100 Pale Crepe
Tested at Ambient:						
Tensile, psi	3000	2870	3140	2920	3210	3200
Modulus @100% Elongation, psi	175	240	300	330	335	430
Modulus @200% Elongation, psi	350	535	730	715	885	1105
Modulus @300% Elongation, psi	740	1155	1435	1430	1760	1955
Ultimate Elongation, %	720	590	540	550	510	440
Hardness, Shore A	61	62	67	65	70	72
Tested at 300°F:						
Tensile, psi	1010 (-66)**	1035 (-64)	1325 (-58)	1260 (-57)	1470 (-54)	1545 (-52)
Modulus @100% Elongation, psi	135 (-23)	190 (-21)	235 (-22)	225 (-32)	275 (-18)	280 (-35)
Modulus @200% Elongation, psi	310 (-11)	425 (-21)	510 (-30)	455 (-36)	565 (-36)	500 (-55)
Modulus @300% Elongation, psi	445 (-40)	745 (-35)	820 (-43)	810 (-43)	935 (-47)	820 (-58)
Ultimate Elongation, %	500 (-31)	400 (-32)	380 (-30)	430 (-22)	460 (-10)	480 (+9)
Tested at 400°F:						
Tensile, psi	535 (-82)	485 (-83)	590 (-81)	570 (-80)	510 (-84)	360 (-89)
Modulus @100% Elongation, psi	135 (-23)	145 (-40)	210 (-30)	180 (-45)	170 (-49)	180 (-58)
Modulus @200% Elongation, psi	220 (-37)	290 (-46)	400 (-45)	310 (-57)	310 (-65)	270 (-76)
Modulus @300% Elongation, psi	400 (-46)	485 (-58)	590 (-59)	485 (-66)	475 (-72)	360 (-82)
Ultimate Elongation, %	370 (-49)	300 (-49)	300 (-44)	370 (-33)	360 (-29)	320 (-27)
Tear, Die C, ambient, pi	210	195	200	405	575	365
Tear, Die C, at 250°F, pi	180	200	180	200	255	245
Tear, Die C, at 300°F, pi	180	175	175	160	200	230
ASTM D1043, T200, °F	-33	-37	-35	-43	-44	-52
Abrasion Resistance, Du Pont Abrader, Volume Loss after 25 min., cc, (% of reference compound S223-4)	0.3476 (100)	0.2300 (151)	0.1567 (222)	0.1632 (213)	0.1467 (236)	0.1752 (198)
Crack Growth, DeMattia Tester, 50,000 cycles, 32nds of an inch	8	18	Cracked across 30,000	22	4	2
Time to first crack, 50± 5 pphm Ozone @100± 2°F, 30 days, Bent Loop Specimen	Crack Free	1 Day	1 Day	1 Day	1 Day	1 Day
Specific Gravity	1.15	1.14	1.15	1.14	1.15	1.16

*85/15 Butadiene/Styrene - 37.5 parts oil extended

**Values in parentheses are percent change from original values

TABLE 11
EVALUATION OF HYTRANS 1227-289-2*/PALE CREPE BLENDS

Physical Properties	B33-4 100 HYTRANS	B33-5 110/20 HYTRANS/ Pale Crepe	B33-6 82.5/40 HYTRANS/ Pale Crepe	A53 55/60 HYTRANS/ Pale Crepe	A53-1 27.5/80 HYTRANS/ Pale Crepe	A53-2 100 Pale Crepe
Tested at Ambient:		THIS COMPOUND WAS NOT EVALUATED BECAUSE NOT ENOUGH HYTRANS WAS AVAILABLE TO MIX ALL COMPOUNDS.				
Tensile, psi	2745		2760	3095	3215	3210
Modulus @100% Elongation, psi	185		315	430	470	475
Modulus @200% Elongation, psi	420		735	1110	1305	1200
Modulus @300% Elongation, psi	910		1425	1990	2215	2190
Ultimate Elongation, %	650		510	450	430	440
Hardness, Shore A	60		67	71	72	73
Tested at 300°F:						
Tensile, psi	845 (-69)**		1155 (-58)	2000 (-35)	1360 (-58)	1095 (-66)
Modulus @100% Elongation, psi	190 (+3)		265 (-16)	265 (-38)	340 (-28)	295 (-38)
Modulus @200% Elongation, psi	330 (-21)		480 (-35)	535 (-52)	750 (-43)	675 (-44)
Modulus @300% Elongation, psi	565 (-38)		845 (-41)	845 (-58)	1120 (-49)	1095 (-50)
Ultimate Elongation, %	400 (-38)		390 (-4)	550 (+22)	380 (-12)	300 (-33)
Tested at 400°F:						
Tensile, psi	475 (-83)		515 (-81)	430 (-86)	515 (-84)	475 (-85)
Modulus @100% Elongation, psi	135 (-27)		130 (-59)	130 (-70)	170 (-64)	175 (-63)
Modulus @200% Elongation, psi	240 (-43)		305 (-59)	260 (-77)	340 (-74)	385 (-68)
Modulus @300% Elongation, psi	415 (-54)		515 (-64)	365 (-82)	470 (-79)	--
Ultimate Elongation, %	320 (-51)		300 (-41)	390 (-13)	330 (-23)	260 (-41)
Tear, Die C, ambient, pi	190		310	365	415	535
Tear, Die C, at 250°F, pi	195		215	215	245	320
Tear, Die C, at 300°F, pi	120		145	160	165	255
ASTM D1043, T200, °F	-52		-51	-48	-45	-46
Abrasion Resistance, Du Pont Abrader, Volume Loss after 25 min., cc, (% of reference compound B33-4)	0.1095 (100)		0.1550 (71)	0.1273 (86)	0.1505 (73)	0.2606 (42)
Crack Growth, DeMattia Tester, 50,000 cycles, 32nds of an inch	18		Cracked across 40,000	20	20	2
Time to first crack, 50± 5 pphm Ozone @100± 2°F, 30 days, Bent Loop Specimen	Crack Free		1 Day	1 Day	1 Day	1 Day
Specific Gravity	1.14		1.15	1.16	1.16	1.17

*90/10 Butadiene/Isoprene - 37.5 parts oil extended

** Values in parentheses are percent change from original values

TABLE 12
EVALUATION OF PHILPRENE 1609/CIS-4 1350/PALE CREPE BLENDS

Physical Properties	S212-2 101.5/64.5 1609/1350	S212-5 1609 - 81.2 1350 - 51.6 Pale Crepe - 20 Statex 160 - 14	S212-6 1609 - 60.9 1350 - 38.7 Pale Crepe - 40 Statex 160 - 28	A54 1609 - 40.6 1350 - 25.8 Pale Crepe - 60 Statex 160 - 42	A54-1 1609 - 20.3 1350 - 12.9 Pale Crepe - 80 Statex 160 - 56	A54-2 Pale Crepe - 100 Statex 160 - 70
Tested at Ambient:						
Tensile, psi	2350	2410	2940	3280	3295	3245
Modulus @100% Elongation, psi	250	240	335	405	395	355
Modulus @200% Elongation, psi	455	580	715	895	965	935
Modulus @300% Elongation, psi	1015	1205	1380	1665	1800	1780
Ultimate Elongation, %	560	480	530	530	520	530
Hardness, Shore A	59	62	66	68	72	72
Tested at 300°F:						
Tensile, psi	615 (-74)*	875 (-64)	1095 (-63)	1320 (-60)	1455 (-56)	1875 (-42)
Modulus @100% Elongation, psi	150 (-40)	190 (-21)	235 (-30)	235 (-42)	260 (-37)	215 (-39)
Modulus @200% Elongation, psi	355 (-22)	445 (-23)	470 (-34)	520 (-42)	545 (-44)	385 (-59)
Modulus @300% Elongation, psi	615 (-39)	840 (-30)	845 (-39)	830 (-50)	910 (-49)	610 (-66)
Ultimate Elongation, %	300 (-46)	310 (-35)	360 (-32)	400 (-25)	480 (-8)	720 (+34)
Tested at 400°F:						
Tensile, psi	460 (-80)	505 (-78)	565 (-38)	540 (-80)	500 (-85)	405 (-88)
Modulus @100% Elongation, psi	150 (-40)	185 (-23)	190 (-43)	180 (-56)	180 (-54)	135 (-62)
Modulus @200% Elongation, psi	255 (-44)	320 (-45)	330 (-54)	315 (-66)	310 (-68)	225 (-76)
Modulus @300% Elongation, psi	460 (-55)	505 (-58)	525 (-62)	540 (-68)	455 (-75)	270 (-85)
Ultimate Elongation, %	300 (-46)	300 (-38)	310 (-42)	300 (-43)	380 (-27)	460 (-13)
Tear, Die C, ambient, pi	205	205	280	555	555	535
Tear, Die C, at 250°F, pi	145	165	190	245	270	305
Tear, Die C, at 300°F, pi	135	160	175	185	185	255
ASTM D1043, T200, °F	-56	-57	-57	-53	-51	-56
Abrasion Resistance, Du Pont Abrader, Volume Loss after 25 min., cc, (% of reference compound S212-2)	0.2049 (100)	0.1474 (139)	0.1612 (127)	0.1576 (130)	0.1614 (127)	0.2447 (84)
Crack Growth, DeMattia Tester, 50,000 cycles, 32nds of an inch	15	24	28	8	3	2
Time to first crack, 50± 5 pphm Ozone @100± 2°F, 30 days, Bent Loop Specimen	Crack Free	Crack Free	Crack Free	Crack Free	Crack Free	1 Day
Specific Gravity	1.13	1.14	1.14	1.15	1.16	1.16

*Values in parentheses are percent change from original values

TABLE 13
EVALUATION OF BLENDS OF AMERIPOL SN 600 WITH VARIOUS ELASTOMERS

Physical Properties	S152-1 100 SBR 1500	A50-6 40/60 SBR 1500/ Ameripol SN 600	S227-2 100 Stereon 750	A51-3 55/60 Stereon 750/ Ameripol SN 600	S212-2 101.5/64.5 Philprene 1609/ Cis-4 1351	A54-3 1609-40.6 1351-25.8 SN 600-60 Statex 160-42
Tested at Ambient:						
Tensile, psi	4100	2720	2810	2720	2350	3000
Modulus @100% Elongation, psi	375	375	190	375	250	340
Modulus @200% Elongation, psi	845	800	335	800	455	625
Modulus @300% Elongation, psi	1820	1545	665	1545	1015	1285
Ultimate Elongation, %	510	440	730	440	560	560
Hardness, Shore A	66	62	56	62	59	67
Tested at 300°F:						
Tensile, psi	980(-76)*	1085(-60)	855(-69)	1015(-63)	615(-74)	1175(-61)
Modulus @100% Elongation, psi	310(-17)	270(-28)	145(-24)	205(-45)	150(-40)	235(-31)
Modulus @200% Elongation, psi	710(-16)	670(-16)	285(-15)	455(-43)	355(-22)	460(-26)
Modulus @300% Elongation, psi	--	1085(-30)	460(-31)	760(-51)	615(-39)	715(-44)
Ultimate Elongation, %	280(-45)	300(-32)	500(-32)	400(-9)	300(-46)	450(-20)
Tear, Die C, ambient, pi	230	200	225	335	205	475
Tear, Die C, at 250°F, pi	110	195	175	295	145	240
Tear, Die C, at 300°F, pi	95	170	150	225	135	180
Crack Growth, DeMattia Tester; 50,000 cycles, 32nds of an inch	23	9	18	1	15	1
ASTM D1043, T200, °F	-26	-55	-58	-65	-56	-64
Abrasion Resistance, Du Pont Abrader, Vol. Loss after 25 mins., cc, (% of reference compound S152-1)	1.111 (100)	0.206 (539)	0.176 (631)	0.147 (756)	0.205 (542)	0.229 (485)
Time to first crack, 50±5 pphm Ozone @100-2°F, 30 days, Bent Loop Specimen	Crack Free	Crack Free	Crack Free	< 4 Hours	Crack Free	Crack Free
Specific Gravity	1.15	1.12	1.14	1.14	1.13	1.15

*Values in parentheses are percent change from original values

TABLE 13(Continued)

Physical Properties	S223-4 100 HYTRANS-A (SBR type)	A52-3 55/60 HYTRANS A/ Ameripol SN 600	B33-4 100 HYTRANS B (Butadiene/Isoprene type)	A53-3 55-60 HYTRANS B/ Ameripol SN 600
Tested at Ambient:				
Tensile, psi	3000	2410	2745	3060
Modulus @100% Elongation, psi	175	390	185	330
Modulus @200% Elongation, psi	350	965	420	930
Modulus @300% Elongation, psi	740	1735	910	1740
Ultimate Elongation, %	720	410	650	470
Hardness, Shore A	61	70	60	70
Tested at 300° F:				
Tensile, psi	1010(-66)*	1015(-58)	845(-69)	1130(-63)
Modulus @ 100% Elongation, psi	135(-23)	305(-22)	190(+3)	330(0)
Modulus @200% Elongation, psi	310(-11)	610(-37)	330(-21)	660(-29)
Modulus @300% Elongation, psi	445(-40)	910(-48)	565(-38)	1035(-41)
Ultimate Elongation, %	500(-31)	320(-22)	400(-38)	330(-30)
Tear, Die C, ambient, pi	210	200	190	205
Tear, Die C, at 250°F, pi	180	205	195	205
Tear, Die C, at 300°F, pi	180	150	120	155
Crack Growth, DeMattia Tester; 50,000 cycles, 32nds of an inch	8	13	18	12
ASTM D1043, T200, °F	-33	-56	-52	-71
Abrasion Resistance, Du Pont Abrader, Vol. Loss after 25 mins., cc (% of reference compound SI' 2-1)	0.348 (319)	0.189 (588)	0.110 (1010)	0.123 (903)
Time to first crack, 50±5 pphm Ozone @100 ±2°F, 30 days Bent Loop Specimen	Crack Free	< 6 Hours	Crack Free	< 4 Hours
Specific Gravity	1.15	1.16	1.14	1.15

*Values in parentheses are percent change from original values

TABLE 14
EVALUATION OF EP SYN 55(EPDM)/PALE CREPE BLENDS

Physical Properties	E59 100 EP syn 55	E59-13 60/40 EP syn 55/ Pale Crepe	E59-14 40/60 EP syn 55/ Pale Crepe	E59-15 40/60 EP syn 55/ Pale Crepe (Dyphos)	E59-16 40/60 EP syn 55/ Pale Crepe (Rio Resin)
Tested at Ambient:					
Tensile, psi	3500	3200	3230	2990	2455
Modulus @100% Elongation, psi	275	455	335	445	230
Modulus @200% Elongation, psi	495	965	855	1085	550
Modulus @300% Elongation, psi	990	1775	1785	2025	1100
Ultimate Elongation, %	610	460	460	410	580
Hardness, Shore A	65	67	65	65	63
Tested at 300°F:					
Tensile, psi	890(-74)*	845(-74)	1115(-65)	1100(-63)	1050(-57)
Modulus @100% Elongation, psi	215(-22)	320(-30)	240(-28)	295(-34)	150(-35)
Modulus @200% Elongation, psi	430(-13)	635(-34)	555(-35)	635(-41)	295(-46)
Modulus @300% Elongation, psi	790(-20)	--	910(-49)	1050(-48)	490(-55)
Ultimate Elongation, %	320(-48)	280(-39)	380(-17)	330(-20)	560(-3)
Tested at 400°F:					
Tensile, psi	580(-83)	650(-80)	1115(-65)	665(-78)	650(-54)
Modulus @100% Elongation, psi	225(-18)	240(-47)	205(-39)	200(-55)	100(-57)
Modulus @200% Elongation, psi	580(+17)	575(-40)	455(-47)	490(-55)	200(-64)
Modulus @300% Elongation, psi	--	--	725(-59)	--	350(-68)
Ultimate Elongation, %	200(-67)	240(-48)	310(-33)	270(-34)	500(-14)
Tear, Die C, ambient, pi	260	195	180	170	170
Tear, Die C, at 250°F, pi	160	130	155	165	175
Tear, Die C, at 300°F, pi	140	120	140	140	155
Crack Growth, DeMattia Tester; 50,000 cycles, 32nds of an inch	8	3	1	1	0

*Values in parentheses are percent change from original values

TABLE 14 (Continued)

Physical Properties	E59 100 EP syn 55	E59-13 60/40 EP syn 55/ Pale Crepe	E59-14 40/60 EP syn 55/ Pale Crepe	E59-15 40/60 EP syn 55/ Pale Crepe (Dyphos)	E59-16 40/60 EP syn 55/ Pale Crepe (Rio Resin)
ASTM D1043, T200, °F	-46	-59	-61	-64	-63
Abrasion Resistance, Du Pont Abrader, Vol. Loss after 25 mins., cc, (% of reference compound S152-1)	1.273 (91)	1.380 (83)	0.086 (1346)	1.189 (97)	0.237 (489)
Time to first crack, 50±5 pphm Ozone @100±2°F, 30 days, Bent Loop Specimen	Crack Free	Crack Free	Crack Free	Crack Free	Crack Free
Specific Gravity	1.07	1.10	1.10	1.11	1.09

*Values in parentheses are percent change from original values

TABLE 15
EVALUATION OF AMERIPOL 4713 FOR POTENTIAL TRACK PAD USE

Physical Properties	S152-1 SBR 1500	S252 Ameripol 4713
Tested at Ambient:		
Tensile, psi	4140	3225
Modulus @100% Elongation, psi	310	375
Modulus @200% Elongation, psi	960	955
Modulus @300% Elongation, psi	2020	1880
Ultimate Elongation, %	480	460
Hardness, Shore A	65	68
Tested at 300°F:		
Tensile, psi	770 (-81)	810 (-75)
Modulus @100% Elongation, psi	310 (0)	265 (-29)
Modulus @200% Elongation, psi	760 (-21)	720 (-25)
Modulus @300% Elongation, psi	--	--
Ultimate Elongation, %	210 (-56)	280 (-39)
Tested at 400°F:		
Tensile, psi	420 (-90)	410 (-87)
Modulus @100% Elongation, psi	260 (-16)	410 (+9)
Modulus @200% Elongation, psi	--	--
Modulus @300% Elongation, psi	--	--
Ultimate Elongation, %	150 (-69)	100 (-78)
Tear, Die C, ambient, pi	215	200
Tear, Die C, at 250°F, pi	130	180
Tear, Die C, at 300°F, pi	80	165
ASTM D1043, T200, °F	-35	-27
Abrasion Resistance Du Pont Abrader Volume, Loss after 25 min., cc, (% of reference compound S152-1)	1.0481 (100)	0.2637 (397)
Crack Growth, De Mattia Tester, 50,000 cycles, 32nds of an inch	Cracked across 50,000 cycles	Cracked across 40,000 cycles
Time to first crack, 50 ± 5 pphm Ozone @100 ± 2°F, 30 days, Bent Loop Specimen	Crack Free	Crack Free
Specific Gravity	1.13	1.22

TABLE 16

EVALUATION OF STEREON 750/BROMOBUTYL/EPDM BLENDS (SAF vs. FEF BLACK)

Physical Properties		70 SAF BLACK		35/35 SAF/FEF BLACK			70 FEF BLACK		
	S227-2 Stereon 137.5	S227-22 Stereon 110 Bromobutyl 20 Oil 7.5	S227-23 Stereon 82.5 Bromobutyl 20 EPDM 20 Oil 15	S227-27 Stereon 137.5	S227-28 Stereon 110 Bromobutyl 20 Oil 7.5	S227-29 Stereon 82.5 Bromobutyl 20 EPDM 20 Oil 15	S227-24 Stereon 137.5	S227-25 Stereon 110 Bromobutyl 20 Oil 7.5	S227-26 Stereon 82.5 Bromobutyl 20 EPDM 20 Oil 15
Tested at Ambient:									
Tensile, psi	2900	2685	2125	2630	2325	2105	2295	2055	1840
Modulus @100% Elongation, psi	255	245	260	205	205	255	265	270	265
Modulus @200% Elongation, psi	355	535	625	355	505	690	640	650	640
Modulus @300% Elongation, psi	655	1025	1245	820	1015	1335	1120	1135	1120
Ultimate Elongation, psi	730	600	510	680	580	510	650	570	510
Hardness, Shore A	56	59	61	54	55	60	53	54	55
Tested at 300°F:									
Tensile, psi	840(-70)*	975(-64)	830(-61)	830(-68)	925(-60)	760(-64)	895(-61)	800(-61)	640(-65)
Modulus @100% Elongation, psi	150(-41)	195(-20)	210(-19)	210(+2)	160(-22)	200(-22)	210(-21)	215(-20)	215(-19)
Modulus @200% Elongation, psi	295(-17)	390(-27)	470(-25)	365(+3)	370(-27)	555(-20)	475(-26)	475(-27)	535(-16)
Modulus @300% Elongation, psi	440(-33)	635(-38)	780(-37)	630(-23)	630(-38)	--	685(-39)	705(-38)	--
Ultimate Elongation, %	510(-30)	450(-25)	320(-37)	450(-34)	400(-31)	270(-47)	380(-42)	360(-37)	230(-53)
Tear, Die C, ambient, pi	225	195	170	215	195	170	215	190	160
Tear, Die C, at 250°F, pi	225	170	125	195	165	125	140	120	70
Crack Growth, DeMattia Tester; 50,000 cycles, 32nds of an inch	13	13	14	7	4	5	1	0	0
ASTM D1043, T200, °F	-77	-67	-64	-73	-73	-65	-78	-73	-68
Abrasion Resistance, Du Pont Abrader, Vol. Loss After 25 mins., cc, (% of reference cpd. S152-1)	0.187 (619)	0.228 (508)	0.229 (506)	0.210 (551)	0.301 (385)	0.248 (467)	0.218 (531)	0.423 (274)	0.715 (162)
Time to first crack, 50±5 pphm Ozone @100 ± 2°F, 30 days Bent Loop Specimen	Crack Free	Crack Free	Crack Free	Crack Free	Crack Free	Crack Free	Crack Free	Crack Free	Crack Free
Sp. Gravity	1.14	1.14	1.13	1.15	1.14	1.14	1.15	1.14	1.13

*Values in parentheses are percent change from original value

TABLE 17

EVALUATION OF HYTRANS (SBR TYPE)/BROMOBUTYL/EPDM BLENDS (SAF vs. FEF BLACK)

Physical Properties	70 SAF BLACK			35/35 SAF/FEF BLACK			70 FEF BLACK		
	S223-4 HYTRANS 137.5	S223-29 HYTRANS 110 Bromobutyl 20 Oil 7.5	S223-30 HYTRANS 82.5 Bromobutyl 20 EPDM 20 Oil 15	S223-34 HYTRANS 137.5	S223-35 HYTRANS 110 Bromobutyl 20 Oil 7.5	S223-36 HYTRANS 82.5 Bromobutyl 20 EPDM 20 Oil 15	S223-31 HYTRANS 137.5	S223-32 HYTRANS 110 Bromobutyl 20 Oil 7.5	S223-33 HYTRANS 82.5 Bromobutyl 20 EPDM20 Oil 15
Tested at Ambient:									
Tensile, psi	3035	2600	2715	2855	2400	2280	2370	2135	1920
Modulus @100% Elongation, psi	195	200	200	160	215	265	215	270	310
Modulus @200% Elongation, psi	340	400	550	460	520	695	370	755	780
Modulus @300% Elongation, psi	730	850	1250	975	1075	1215	1105	1300	1300
Ultimate Elongation, %	700	620	590	720	600	530	620	540	460
Hardness, Shore A	56	58	63	54	55	58	51	51	57
Tested at 300°F:									
Tensile, psi	1035(-66)*	890(-66)	915(-66)	960(-66)	810(-66)	760(-67)	1055(-55)	935(-56)	855(-55)
Modulus @100% Elongation, psi	150(-23)	150(-25)	195(-3)	155(-3)	155(-28)	205(-23)	215(0)	215(-20)	270(-13)
Modulus @200% Elongation, psi	295 (-13)	345(-14)	385(-30)	360(-22)	410(-21)	455(-34)	525(+42)	535(-29)	695(-11)
Modulus @300% Elongation, psi	495(-32)	495(-42)	675(-46)	610(-37)	610(-43)	710(-42)	055(-19)	[illegible](-34)	--
Ultimate Elongation, %	500(-29)	460(-26)	400(-32)	450(-38)	400(-33)	340(-36)	350(-44)	320(-41)	250
Tear, Die C, ambient, pi	225	185	195	225	175	165	225	175	170
Tear, Die C, at 250°F, pi	240	235	185	240	185	165	90	90	70
Crack Growth, DeMattia Tester; 50,000 cycles, 32nds of an inch	4	14	11	3	7	6	1	1	4
ASTM D1043, T200, °F	-47	-46	-45	-49	-50	-49	-51	-52	-55
Abrasion Resistance, Du Pont Abrader, Vol. Loss after 25 mins., cc, (% of reference cpd. S152-1)	0.311 (372)	0.947 (122)	0.308 (376)	1.318 (88)	1.227 (94)	0.611 (190)	1.248 (93)	1.194 (97)	1.362 (85)
Time to first crack, 50$\pm$5 pphm Ozone @100 $\pm$2°F, 30 days, Bent Loop Specimen	Crack Free	Crack Free	Crack Free	Crack Free	Crack Free	Crack Free	Crack Free	Crack Free	Crack Free
Sp. Gravity	1.14	1.14	1.13	1.14	1.14	1.13	1.15	1.15	1.13

*Values in parentheses are percent change from original value

TABLE 18

EVALUATION OF HYTRANS (BUTADIENE, ISOPRENE TYPE)/BROMOBUTYL/EPDM BLENDS (SAF vs. FEF BLACK)

Physical Properties	70 SAF BLACK B33-4 HYTRANS 137.5	B33-7 HYTRANS 110 Bromobutyl 20 Oil 7.5	B33-8 HYTRANS 82.5 Bromobutyl 20 EPDM 20 Oil 15	35/35 SAF/FEF BLACK B33-12 HYTRANS 137.5	B33-13 HYTRANS 110 Bromobutyl 20 Oil 7.5	B33-14 HYTRANS 82.5 Bromobutyl 20 EPDM 20 Oil 15	70 FEF BLACK B33-9 HYTRANS 137.5	B33-10 HYTRANS 110 Bromobutyl 20 Oil 7.5	B33-11 HYTRANS 82.5 Bromobutyl 20 EPDM 20 Oil 15
Tested at Ambient:									
Tensile, psi	3000	2745	1685	2775	2355	2250	2370	2000	2000
Modulus @100% Elongation, psi	250	205	290	245	200	250	265	265	315
Modulus @200% Elongation, psi	450	385	675	535	495	650	685	630	895
Modulus @300% Elongation, psi	900	865	1155	1085	990	1250	1195	1145	1475
Ultimate Elongation, %	650	660	410	610	600	490	560	500	400
Hardness, Shore A	58	59	63	56	55	58	52	53	56
Tested at 300°F:									
Tensile, psi	905(-70)*	925(-66)	585(-65)	815(-71)	750(-68)	690(-69)	885(-63)	710(-65)	585(-71)
Modulus @100% Elongation, psi	190(-24)	145(-29)	205(-29)	245(0)	150(-25)	200(-20)	260(-2)	205(-23)	265(-16)
Modulus @200% Elongation, psi	380(-16)	340(-12)	440(-35)	495(-7)	350(-29)	470(-28)	570(-17)	455(-28)	585(-35)
Modulus @300% Elongation, psi	570(-37)	490(-43)	--	815(-25)	600(-39)	--	885(-26)	710(-38)	--
Ultimate Elongation, %	410(-37)	480(-27)	270(-34)	350(-43)	390(-35)	300(-39)	300(-46)	300(-40)	200(-50)
Tear, Die C, ambient, pi	215	200	180	200	185	170	205	180	155
Tear, Die C, at 250°F, pi	190	170	110	190	190	100	100	80	60
Crack Growth, DeMattia Tester; 50,000 cycles, 32nds of an inch	15	20	Cracked **Across** 50,000	12	16	11	6	0	3
ASTM D1043, T200, °F	-71	-73	-67	-73	-73	-67	-75	-73	-72
Abrasion Resistance, Du Pont Abrader, Vol. Loss after 25 mins., cc, (% of reference cpd. S152-1)	0.089 (1301)	0.206 (562)	0.224 (517)	0.098 (1182)	0.277 (418)	0.359 (325)	0.444 (261)	1.080 (107)	0.790 (147)
Time to 1st crack, 50±5 pphm Ozone @100±2°F, 30 days, Bent Loop Specimen	Crack Free	Crack Free	Crack Free	Crack Free	Crack Free	Crack Free	Crack Free	Crack Free	Crack Free
Sp. Gravity	1.12	1.12	1.11	1.13	1.13	1.12	1.13	1.13	1.12

*Values in parentheses are percent change from original value

TABLE 19
EVALUATION OF SANTOWEB D IN SBR 1500

Physical Properties	S152-1 Santoweb D-0	S152-186 Santoweb D-5	S152-187 Santoweb D-15
Tested at Ambient:			
Tensile, psi	4355	3400	2870
Modulus @100% Elongation, psi	420	650	720
Modulus @200% Elongation, psi	1000	1300	1130
Modulus @300% Elongation, psi	2105	2450	1925
Ultimate Elongation, %	510	410	400
Hardness, Shore A	69	80	86
Tested at 300°F:			
Tensile, psi	1090(-75)*	750(-78)	550(-81)
Modulus @100% Elongation, psi	310(-26)	450(-31)	425(-41)
Modulus @200% Elongation, psi	780(-22)	--	--
Modulus @300% Elongation, psi	--	--	--
Ultimate Elongation, %	270(-47)	170(-59)	170(-58)
Tear, Die C, ambient, pi	225	240	265
Tear, Die C, at 250°F, pi	115	105	105
Crack Growth, DeMattia Tester; 50,000 cycles, 32nds of an inch	22	Cracked Across 20,000	Cracked Across 20,000
ASTM D1043, T200, °F	-44	-38	-37
Abrasion Resistance, Du Pont Abrader, Vol. Loss after 25 mins., cc, (% of reference compound S152-1)	0.925 (100)	1.080 (86)	1.350 (69)
Time to first crack, 50±5 pphm Ozone @100±2°F, 30 days Bent Loop Specimen	Crack Free	< 1 Day	< 1 Day
Sp. Gravity	1.15	1.16	1.16

*Values in parentheses are percent change from original values

TABLE 20
EVALUATION OF SANTOWEB D IN SBR 1500/PALE CREPE BLEND

Physical Properties	A50-3 Santoweb D-0	A50-7 Santoweb D-5	A50-8 Santoweb D-15
Tested at Ambient:			
Tensile, psi	3530	3430	2480
Modulus @100% Elongation, psi	355	520	790
Modulus @200% Elongation, psi	960	1040	1265
Modulus @300% Elongation, psi	1820	1920	1920
Ultimate Elongation, %	510	490	370
Hardness, Shore A	66	76	82
Tested at 300°F:			
Tensile, psi	1100(-69)*	1165(-66)	780(-69)
Modulus @100% Elongation, psi	300(-15)	355(-32)	415(-47)
Modulus @200% Elongation, psi	650(-32)	610(-41)	625(-51)
Modulus @300% Elongation, psi	1050(-42)	960(-50)	--
Ultimate Elongation, %	320(-37)	350(-29)	250(-32)
Tear, Die C, ambient, pi	205	245	315
Tear, Die C, at 250°F, pi	190	190	185
Crack Growth, DeMattia Tester; 50,000 cycles, 32nds of an inch	15	20	Cracked Across 40,000
ASTM D1043, T200, °F	-55	-53	-48
Abrasion Resistance, Du Pont Abrader, Vol. Loss after 25 min., cc, (% of reference compound A50-3)	0.091 (100)	1.243 (8)	1.227 (7)
Time to first crack, 50±5 pphm Ozone @100±2°F, 30 days, Bent Loop Specimen	Crack Free	< 1 Day	< 1 Day
Sp. Gravity	1.13	1.14	1.14

*Values in parentheses are percent change from original value

TABLE 21

EVALUATION OF SANTOWEB D IN STEREON 750

Physical Properties	S227-2 Santoweb D-0	S227-30 Santoweb D-5	S227-31 Santoweb D-15
Tested at Ambient:			
Tensile, psi	2840	2820	2280
Modulus @100% Elongation, psi	255	360	405
Modulus @200% Elongation, psi	445	565	555
Modulus @300% Elongation, psi	890	1075	910
Ultimate Elongation, %	570	570	570
Hardness, Shore A	57	67	72
Tested at 300°F:			
Tensile, psi	910(-68)*	940(-67)	675(-71)
Modulus @100% Elongation, psi	205(-20)	255(-29)	210(-48)
Modulus @200% Elongation, psi	355(-20)	410(-27)	365(-34)
Modulus @300% Elongation, psi	595(-33)	665(-38)	515(-43)
Ultimate Elongation, %	420(-26)	390(-32)	400(-30)
Tear, Die C, ambient, pi	215	225	265
Tear, Die C, at 250°F, pi	170	160	160
Crack Growth, DeMattia Tester; 50,000 cycles 32nds of an inch	19	Cracked Across 40,000	29
ASTM D1043	-65	-61	-59
Abrasion Resistance, Du Pont Abrader, Vol. Loss after 25 min., cc, (% of reference compound S227-2)	0.157 (100)	0.110 (143)	0.141 (111)
Time to first crack, 50±5 pphm Ozone @100±2°F, 30 days, Bent Loop Specimen	Crack Free	< 1 Day	< 1 Day
Sp. Gravity	1.14	1.15	1.15

*Values in parentheses are percent change from original values

Table 22

EVALUATION OF SANTOWEB D IN PHILPRENE 1609/CIS-4 1351 BLEND

Physical Properties	S212-2 Santoweb D-0	S212-18 Santoweb D-5	S212-19 Santoweb D-15
Tested at Ambient:			
Tensile, psi	2630	2160	2000
Modulus @100% Elongation, psi	210	325	370
Modulus @200% Elongation, psi	525	485	525
Modulus @300% Elongation, psi	945	840	790
Ultimate Elongation, %	580	580	600
Hardness, Shore A	56	67	77
Tested at 300°F:			
Tensile, psi	905(-66)*	865(-59)	795(-60)
Modulus @100% Elongation, psi	215(+2)	205(-37)	240(-35)
Modulus @200% Elongation, psi	475(-10)	380(-22)	410(-22)
Modulus @300% Elongation, psi	830(-12)	685(-18)	585(-26)
Ultimate Elongation, %	320(-45)	360(-38)	370(-29)
Tear, Die C, ambient, pi	225	235	265
Tear, Die C, at 250°, pi	135	170	170
Crack Growth, DeMattia Tester, 50,000 cycles, 32nds of an inch	13	16	24
ASTM D1043, T200, °F	-60	-62	-57
Abrasion Resistance, Du Pont Abrader, Vol. Loss after 25 min., cc, (% of reference compound S212-2)	0.370 (100)	1.038 (36)	1.221 (30)
Time to first crack, 50±5 pphm Ozone @ 100±2°F, 30 days, Bent Loop Specimen	Crack Free	Crack Free	Crack Free
Sp. Gravity	1.12	1.13	1.13

*Values in parentheses are percent change from original values

TABLE 23
EVALUATION OF SANTOWEB D IN HYTRANS (SBR TYPE)

Physical Properties	S223-4 Santoweb D-0	S223-37 Santoweb D-5	S223-38 Santoweb D-15
Tested at Ambient:			
Tensile, psi	2925	2785	2440
Modulus @100% Elongation, psi	205	255	365
Modulus @200% Elongation, psi	355	355	520
Modulus @300% Elongation, psi	780	760	935
Ultimate Elongation, %	660	690	570
Hardness, Shore A	57	62	72
Tested at 300°F:			
Tensile, psi	1000(-66)*	925(-67)	770(-68)
Modulus @100% Elongation, psi	150(-27)	155(-39)	255(-30)
Modulus @200% Elongation, psi	345(-59)	310(-13)	410(-21)
Modulus @300% Elongation, psi	545(-30)	460(-39)	565(-40)
Ultimate Elongation, %	440(-33)	500(-28)	400(-30)
Tear, Die C, ambient, pi	215	235	240
Tear, Die C, at 250°F, pi	205	155	155
Crack Growth, DeMattia Tester; 50,000 cycles, 32nds of an inch	9	9	16
ASTM D1043, T200, °F	-33	-37	-34
Abrasion Resistance, Du Pont Abrader, Vol. Loss after 25 min., cc, (% of reference compound S223-4)	0.162 (100)	0.275 (59)	1.126 (14)
Time to first crack, 50±5 pphm Ozone @ 100±2°F, 30 days, Bent Loop Specimen	Crack Free	< 2 Hours	< 2 Hours
Sp. Gravity	1.15	1.16	1.16

*Values in parentheses are percent change from original values

TABLE 24

EVALUATION OF SANTOWEB D IN HYTRANS (BUTADIENE/ISOPRENE TYPE)

Physical Properties	B33-4 Santoweb D-0	B33-15 Santoweb D-5	B33-16 Santoweb D-15
Tested at Ambient:			
Tensile, psi	3210	2500	2050
Modulus @100% Elongation, psi	200	300	310
Modulus @200% Elongation, psi	495	450	460
Modulus @300% Elongation, psi	990	900	720
Ultimate Elongation, %	620	590	540
Hardness, Shore A	58	64	74
Tested at 300°F:			
Tensile, psi	1015(-68) *	830(-67)	690(-66)
Modulus @100% Elongation, psi	205(+3)	205(-32)	255(-18)
Modulus @200% Elongation, psi	405(-18)	405(-10)	395(-14)
Modulus @300% Elongation, psi	660(-33)	585(-35)	515(-28)
Ultimate Elongation, %	390(-37)	420(-29)	400(-26)
Tear, Die C, ambient, pi	215	230	245
Tear, Die C, at 250°F, pi	205	190	185
Crack Growth, DeMattia Tester; 50,000 cycles, 32nds of an inch	15	24	24
ASTM D1043, T200, °F	-62	-63	-60
Abrasion Resistance, Du Pont Abrader, Vol. Loss after 25 min., cc, (% of reference compound B33-4)	0.078 (100)	0.089 (88)	0.465 (15)
Time to first crack, 50±5 pphm Ozone @ 100±2°F, 30 days, Bent Loop Specimen	Crack Free	< 2 Hours	< 2 Hours
Sp. Gravity	1.14	1.15	1.15

*Values in parentheses are percent change from original value

TABLE 25

PHYSICAL PROPERTIES OF BANBURY MIXED EXPERIMENTAL T142 TRACK PAD COMPOUNDS

Physical Properties	S152-1	A50-3	S227-2	A51	S223-4	A52	S212-2	A54	S227-21	S152-160	S212-7
Tested at Ambient:											
Tensile, psi	4180	4220	2950	3610	2980	3460	2365	3265	2315	3400	2950
Modulus @100% Elongation, psi	405	300	240	285	220	460	320	475	195	645	345
Modulus @200% Elongation, psi	900	935	525	700	445	1040	720	1115	435	1655	800
Modulus @300% Elongation, psi	1800	1945	970	1400	800	1915	1395	2020	770	3150	1675
Ultimate Elongation, %	530	520	670	580	710	490	430	470	690	310	480
Hardness, Shore A	65	62	58	65	60	69	60	71	50	66	60
Tested at 300°F:											
Tensile, psi	885(-79)*	1345(-68)	855(-71)	1240(-66)	865(-71)	1320(-62)	550(-77)	1070(-67)	620(-73)	955(-72)	895(-70)
Modulus @100% Elongation, psi	280(-31)	300(0)	205(-15)	240(-16)	180(-18)	305(-34)	230(-28)	280(-41)	190(-3)	480(-26)	280(-19)
Modulus @200% Elongation, psi	745(-17)	640(-32)	450(-14)	480(-31)	335(-25)	650(-38)	500(-31)	595(-47)	330(-24)	--	705(-12)
Modulus @300% Elongation, psi	--	1045(-46)	695(-28)	750(-47)	485(-39)	1020(-47)	--	1015(-50)	475(-38)	--	--
Ultimate Elongation, %	230(-57)	350(-33)	390(-42)	460(-21)	450(-37)	370(-24)	230(-47)	320(-32)	350(-49)	150(-52)	260(-46)
Tested at 400°F:											
Tensile, psi	375(-91)	505(-88)	455(-85)	440(-88)	510(-83)	520(-85)	445(-81)	550(-83)	430(-81)	570(-83)	570(-81)
Modulus @100% Elongation, psi	225(-44)	220(-27)	125(-48)	160(-44)	140(-36)	185(-60)	180(-44)	180(-62)	140(-28)	350(-46)	220(-36)
Modulus @200% Elongation, psi	--	420(-55)	245(-53)	280(-60)	280(-37)	370(-64)	355(-51)	330(-70)	235(-46)	--	460(-43)
Modulus @300% Elongation, psi	--	--	370(-62)	390(-72)	420(-48)	520(-73)	--	515(-75)	335(-56)	--	--
Ultimate Elongation, %	150(-72)	270(-48)	350(-48)	330(-43)	360(-49)	300(-39)	240(-44)	320(-32)	360(-43)	140(-55)	230(-53)
Tear, Die C, ambient, pi	220	210	240	625	220	600	230	350	195	160	200
Tear, Die C, at 250°F, pi	105	200	185	250	205	235	125	210	155	70	95
Tear, Die C, at 300°F, pi	85	150	155	170	180	185	105	175	75	40	75
Crack Growth, DeMattia Tester, 50,000 cycles, 32nds of an inch	28	15	22	8	10	13	13	14	12	Cracked across 10,000	29
ASTM D1043, T200, °F	-42	-51	-65	-61	-39	-49	-63	-60	-74	-43	-63
Abrasion Resistance, DuPont Abrader, Volume Loss after 25 min., cc, (% of reference compound S152-1)	1.158 (100)	0.236 (490)	0.171 (676)	0.136 (851)	0.408 (284)	0.171 (678)	0.195 (593)	0.137 (843)	0.857 (135)	1.289 (90)	0.201 (576)
Time to first crack, 50±5pphm Ozone at 100±2°F, 30 days, Bent Loop Specimen	Crack free	Crack free	Crack free	Crack free	Crack free	Crack free	Crack free	Crack free	Crack free	Crack free	Crack free
Specific Gravity	1.14	1.13	1.13	1.15	1.14	1.16	1.13	1.15	1.17	1.16	1.16

*Values in parentheses are percent change from original values

TABLE 26

RESULTS OF 500-MILE T142 TRACK PAD TEST AT
YUMA PROVING GROUND ON PAVED TRACK

Compound	Description	Durability or Volume Wear Rating
S152-1	Research Directorate SBR 1500 Control Compound	99
S152-1	Research Directorate SBR 1500 Control Compound (Rounded contour)	91
A50-3	SBR 1500/Pale Crepe Blend	69
S152-160	SBR 1500 (Dyphos additive)	67
S227-2	Stereon 750	135
S227-2	Stereon 750 (Rounded contour)	139
A51	Stereon 750/Pale Crepe Blend	146
S227-21	Stereon 750 (Reinforced with carbon and mineral fillers - silane coupling agent)	79
S223-4	HYTRANS 1697-259-1 (SBR Type)	147
A52	HYTRANS 1697-259-1/Pale Crepe Blend	150
S212-2	Philprene 1609/Cis-4 1351 Blend	150
A54	Philprene 1609/Cis-4 1351/Pale Crepe Blend	131
S212-7	Philprene 1609/Cis-4 1351 Blend (Dyphos additive)	122
--	Commercial Control (Average of pads from three manufacturers)	100

Note: The larger the volume wear rating figure, the better the wear resistance

APPENDIX

Summary of Work performed by the Research Directorate, General Thomas J. Rodman Laboratory, Rock Island Arsenal, to Improve the Wear Resistance of Rubber Tank Track Pads.

Time Period Covered: FY63 thru FY75, continuously.

Research Directorate Personnel Involved in R&D Effort:

R.F. Shaw (deceased)
Z.T. Ossefort (deceased)
R.E. Ofner
J.W. McGarvey
W.M. Veroeven
J.R. Cerny
E.W. Bergstrom

Funding Agencies:

U.S. Army Materials and Mechanics Research Center
Watertown, MA

U.S. Army Tank-Automotive Command
Warren, MI

Number of Experimental Compounds Prepared and Evaluated - 950

Type of Elastomers or Elastomeric Blends Evaluated (by Trade Name):

Genthane S
Genthane S/EPR 404
Genthane SR
Genthane SR/Estane 5740X7
Genthane SR/Texin 192A
Elastothane 455
Elastothane ZR 625
Vibrathane 5004
Vibrathane 5004/EPR 404
Cyanaprene 4590
Estane 5740X2
Estane 5740X2/Estane 5740X7
Witco MG-2
Cyanaprene VG
Dayco PS-48 (Vulcollan)
Multrathane F66
Estane 58013
Wyandotte "one shot" urea urethane
Adiprene B
Adiprene C
Adiprene CM
Adiprene L-100
SBR 1500/HM EPDM/Diene
SBR 1500/HM EPDM
SBR 1500/Ameripol CB 880
SBR 1500/EP syn 55
SBR 1500/Royalene 200
SBR 1500/Vistalon 6505
SBR 1500/Pale Crepe
SBR 1500/Ameripol SN 600
SBR 1000
Diene HD 55
Diene/HM EPDM
Duradene/HM EPDM
Hycar 1072
Hycar 1072/Diene
Dynagen XP-139
Neoprene W
Neoprene TW
Neoprene GNA/Pale Crepe
Chlorobutyl HT 1066
Chlorobutyl HT 1066/EP syn 55
Polysar V3301
Nordel 1070

Adiprene LD-315
SBR 1500
SBR 1500/Diene
SBR 1500/Nordel 1070
SBR 1500/Nordel 1070/Diene
EP syn 55/Pale Crepe
ECD 2677
ECD 2677/Hypalon 45
ECD 2677/Nordel 1700/Hypalon 45
ECD 729/Nordel 1320
Stereon 750
Stereon 750/EP syn 55
Stereon 750/Bromobutyl
Stereon 750/Bromobutyl/EP syn 55
Stereon 750/Ameripol SN 600
Stereon 750/Pale Crepe
Stereon 700/EP syn 55
Stereon 720/EP syn 55
Stereon 720/Diene
Stereon 720/CB 221
Stereon 720/Cis-4 1350
Philprene 1609/Cis-4 1350 (or Cis-4 1351)
Philprene 1609/Cis-4 1350 (or Cis-4 1351)/Pale Crepe
Philprene 1609/Cis-4 1351/Ameripol SN 600
Ameripol SN 600/Ameripol CB 441
Ameripol 1834/Ameripol CB 1352
Ameripol 4713
SBR 4678/CB 221
EPCAR 346/EPCAR 5465
Paracril UPBE
HYTRANS (SBR Type)
HYTRANS (SBR)/Pale Crepe
HYTRANS (SBR)/Ameripol SN 600
Enjay EPT 3509
Royalene 200
EP syn 55
EP syn 55/Cis-4 1350
EP syn 55/Stereon 750
HYTRANS (SBR)/Bromobutyl
HYTRANS (SBR)Bromobutyl/EP syn 55
HYTRANS (Butadiene/Isoprene Type)
HYTRANS (B/I)/Diene
HYTRANS (B/I)/Bromobutyl
HYTRANS (B/I)/Bromobutyl/EP syn 55
HYTRANS (B/I)/Pale Crepe
HYTRANS (B/I)/Ameripol SN 600
High Mooney SBR

Types of Plastics or Plastic-Like Materials Evaluated

Polycarbonate
Injection moldable glass reinforced Estane polyester and polyether urethanes

Total Number of Service Tests for Which Research Directorate Prepared Experimental Track Pads - 15

Pad Type	No. of Tests	Total Pads Prepared	Total Test Miles Run
T130	7	377	11,311
T142	8	796	10,259

Service Test Sites:

FMC Corporation
San Jose, California

General Motors Test Track
Milford, Michigan

Yuma Proving Ground
Yuma, Arizona

Aberdeen Proving Ground
Aberdeen, Maryland

Type of Service Test Course Terrain:

Asphalt track
Paved track
Dirt and gravel secondary roads
Level and hilly cross-country

Types of Compounds (by Trade Name) from Which Experimental Track Pads Were Prepared:

Research Directorate SBR 1500 control compound
Genthane S (with and without hydrolysis inhibitors)
Genthane SR (with and without hydrolysis inhibitors)

SBR 1500/Diene
Vibrathane 5004
Nordel 1070
Paracril UPBE
Adiprene C
SBR 1500 (contains Fiberglas)
Shell synthetic isoprene
High Mooney SBR
Elastothane ZR 625
Dynagen XP-139
Hycar 1072
SBR 1500 (contains cotton flock)
SBR 1500/Nordel 1470
Stereon 720/Nordel 1440
Chlorobutyl HT-1066
Philprene 1609/Cis-4 1450 (or Cis-4 1351)
SBR 1500/Diene
SBR 4676/CB221
Stereon 750
Stereon 750/EP syn 55
Neoprene GNA/Pale Crepe
HYTRANS (SBR Type)

HYTRANS (Butadiene/Isoprene Type)
Neoprene W
Neoprene TW
Neoprene TW (contains RICS)
ECD 2677
ECD 729/Nordel 1320
Ameripol SN 600/Ameripol CB 441
Ameripol 1834/Ameripol CB 1352
EPCAR 346/EPCAR 5465
SBR 1500/Pale Crepe
Stereon 750/Pale Crepe
HYTRANS (SBR)/Pale Crepe
Philprene 1609/Cis-4 1351/Pale Crepe
Polycarbonate
Injection molded glass reinforced ESTANE urethanes
SBR 1500 (contains rubber impregnated chopped strand-RICS)
HYTRANS (Butadiene/Isoprene Type) (contains RICS)
Philprene 1609/Cis-4 1350 (contains RICS)

Types of Compounds Which Exhibited Significant Improvement in Wear Resistance:

Compound Description	Wear Rating (Durability) Range (Based on 3 or more tests)	Comments
Genthane S	76-123	Elastomer proved to be hydrolytically unstable; moderately expensive; withdrawn from market.
Genthane SR	79-150	Elastomer proved to be hydrolytically unstable; porosity developed in pads run at high speeds; moderately expensive; withdrawn from market.
Stereon 750	110-216	Has advanced to pilot lot test stage.
Philprene 1609/Cis-4 1350 (or Cis-4 1351)	145-196	Has advanced to pilot lot test stage
Ameripol 1634/Ameripol CB 1352	141-171	Did not reach pilot lot test stage because of difficulties encountered by TACOM in obtaining elastomers from B.F.Goodrich.
HYTRANS (SBR Type)	124-179	Has not reached pilot lot test state; commercial availability in doubt.
HYTRANS (Butadiene/Isoprene Type)	126-154	Has not reached pilot lot test stage; commercial availability in doubt

Significant Findings in Efforts to Improve Wear Resistance

1. Significant improvement in wear resistance has been achieved from compounds based on certain low cost, general-purpose type elastomers, namely Stereon 750, HYTRANS copolymers of butadiene/styrene or butadiene/isoprene and SBR/polybutadiene blends.

2. Numerous reinforcing agents, other than or in addition to carbon black, were evaluated in various elastomers. These included cotton flock, Nylon flock, Dacron flock, Fiberglas rubber impregnated chopped one inch strand

(RICS) (Owens-Corning), 100:100 lignin: rubber latex coprecipitates (National Research Council of Canada), Duoform 3/4 inch fiber wire (National Standards Co.), brass-plated and low-carbon electro galvanized wire cloth (National Standard Co.) and Santoweb D, an unregenerated cellulose fiber (Monsanto Chemical Co.). None of the reinforcing agents were effective in providing compounds with significant improvement in wear resistance.

3. A 50/50 combination of U.O.P. 88/Santoflex AW significantly improves the resistance to crack growth of vulcanizates based on SBR 1500, Stereon 750, HYTRANS copolymers and an SBR/polybutadiene blend.

4. The blending of natural (pale crepe) or synthetic natural (Ameripol SN 600) rubber with SBR 1500, Stereon 750, HYTRANS copolymers or an SBR/polybutadiene blend significantly improves the resistance to tear, abrasion and crack growth of the resulting vulcanizates.

5. Examination of 17 years of service test data revealed that the main causes of track pad failure were chunking, cutting, abrasion and bond failure. Blowouts (heat buildup) and delamination were infrequent causes of failure. Internal pad temperatures generally averaged 250°F during operation, but temperatures in excess of 350°F have been recorded on occasion.

6. Correlation was found to exist between service test data and laboratory test data for tear, abrasion and crack growth when all three laboratory tests are considered together. In those instances where the laboratory values for tear, abrasion and crack growth are <u>all</u> better than the corresponding values found for the Research Directorate SBR 1500 control compound (S152-1), the service test wear rating is better than that of the Research Directorate control compound which has given wear ratings almost identical to those of commercial SBR pads in numerous service tests. If only one or two of the three properties is inferior to those of the Research Directorate control compound, the wear rating is lower.

7. An invertible rubber track pad was designed and developed by the Research Directorate for the T130 track. In practice the invertible concept provides for double service life by simply inverting the pad to expose a new surface after one surface has become worn. The invertible track pad concept was forwarded to TACOM for their consideration and possible adoption.

8. Injection molding of T130 pads proved feasible. Pads could be injection molded in 5-10 minutes at 350° or 400°F compared to a compression molding time of 75 minutes at 320°F. Physical properties of the injection-molded pads were found to be comparable to those of compression-molded pads. Pilot lots of injection-molded T130 pads have been obtained by

TACOM and are currently being tested. Early results indicate that the wear resistance of the injection-molded pads is significantly better than that of compression-molded pads prepared from the same compounds.

9. Excellent rubber-to-metal vulcanization bonding systems have been found for all the experimental compounds which have exhibited significantly improved wear resistance in service tests.

<u>Technical Reports Issued</u> - 11

1. Rock Island Arsenal Laboratory Technical Report 63-1242, April 1963.
2. Rock Island Arsenal Laboratory Technical Report 63-2900, September 1963.
3. Rock Island Arsenal Laboratory Technical Report 64-2678, September 1964.
4. Rock Island Arsenal Laboratory Technical Report 64-3579, December 1964.
5. Rock Island Arsenal R&E Division Technical Report 66-2517, August 1966.
6. Science and Technology Laboratory Technical Report RE TR 70-121, February 1970.
7. Research Directorate Technical Report RE TR 71-13, July 1971.
8. Research Directorate Technical Report RE TR 71-43, July 1971.
9. Research Directorate Technical Report SWERR-TR 72-74, October 1972.
10. Research Directorate Technical Report R-TR-74-021, April 1974.
11. Research Directorate Technical Report R-TR-76

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WEAR-RESISTANT-RUBBER TANK TRACK PADS, by Edward W. Bergstrom

Report R-TR-76-028, October 1975, 67 p., incl. illus. tables, (PRON A1-5-R0005-01-AW-M5, AMC Code 612105. 11.H8400) Unclassfied report.

Certain chemical heat stabilizers provided a significant reduction in heat buildup to various experimental track pad vulcanizates while others provided a significant improvement in tear resistance at 250°F. Although the resistance to heat buildup through the use of wire cloth may be improved in some cases the use of wire cloth in track pads is not feasible because of the chunking and delamination problems associated with its use under dynamic conditions. Blending natural or synthetic natural rubber with SBR 1500, Stereon 750, HYTRANS or SBR/polybutadiene

UNCLASSIFIED

1. Elastomers
2. Tank Track Pads
3. Service Tests
4. Properties-General
5. Wear Resistance

I. Edward W. Bergstrom
II. Rock Island Arsenal
III. Research Directorate GEN Thomas J. Rodman Lab. Rock Island Arsenal

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